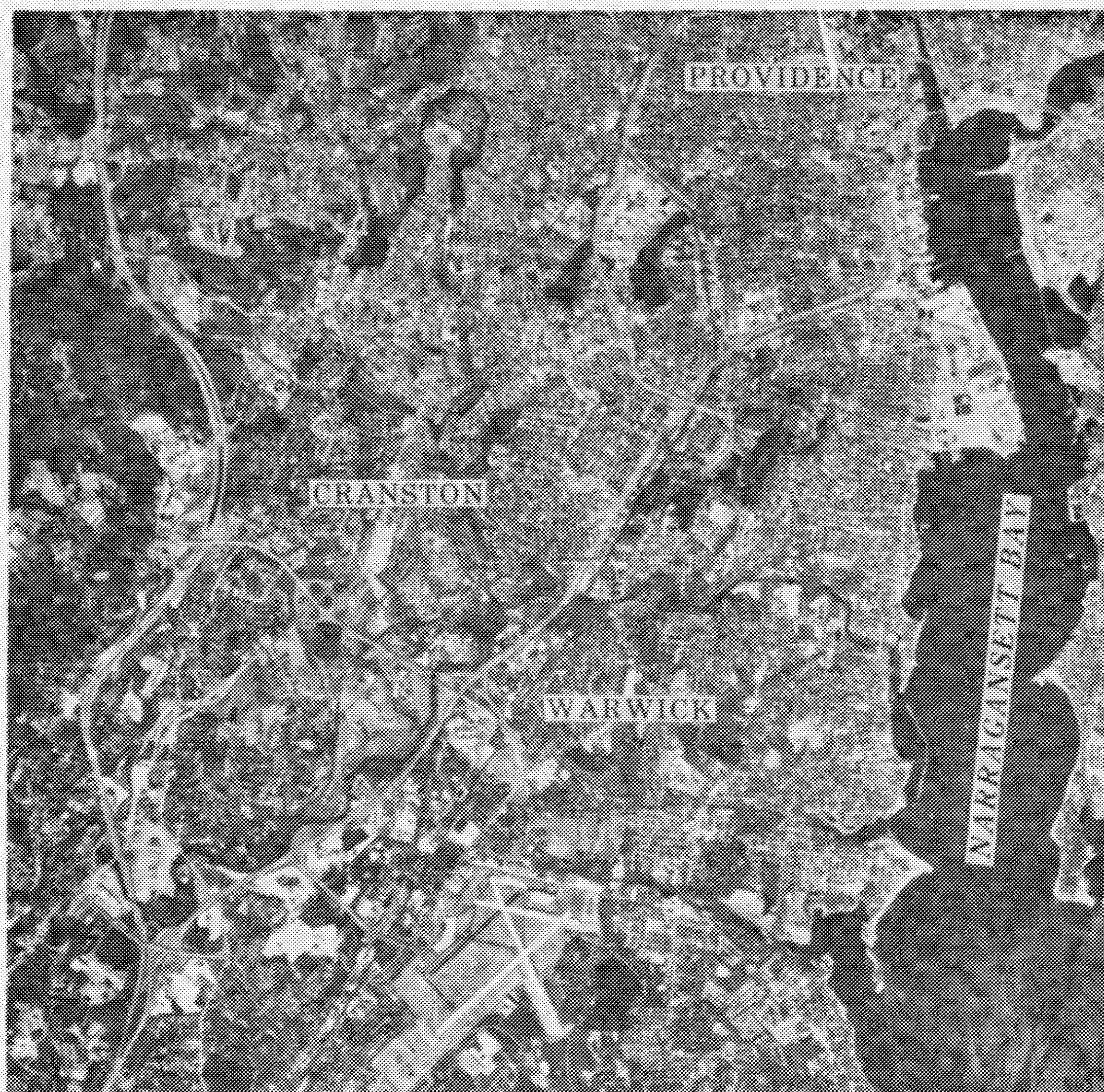
WATER AND RELATED LAND RESOURCES INVESTIGATION

PAWCATUCK RIVER AND
NARRAGANSETT BAY DRAINAGE BASINS

PAWTUXET RIVER WATERSHED
INTERIM REPORT

Planning Aid Report Hydrologic Analysis



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DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

PAWTUXET RIVER FLOOD CONTROL

HYDROLOGIC ANALYSIS

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HYDROLOGIC ANALYSIS

1. PURPOSE

The purpose of this report is to present the hydrologic data and analysis for flood control on the Pawtuxet River. Included are sections on basin description, climatology, analysis of floods and hydrologic engineering related to the plans of improvement for flood control.

2. BASIN DESCRIPTION

a. General. The Pawtuxet River basin shown on plate 1 lies entirely within the State of Rhode Island and covers a total area of 230 square miles. The basin is triangular in shape with a north-south base of 23 miles and an east-west length of about 18 miles. Drainage in the basin is generally west to east and the watershed has a variable hydrologic character. The westerly headwater region is quite hilly with little urban development, whereas the lower easterly portion is very flat and quite highly urbanized. The water resources of the westerly headwater region have been extensively developed for domestic and industrial water supply. Scituate Reservoir with a surface area of 3,400 acres at spillway crest and a drainage area of 93 square miles, is the dominating water supply system in the region. There is little water resource development in the lower basin. Elevations in the basin vary from a high of about 800 feet msl at the westerly divide to a low of 10 feet msl near the mouth of the river.

b. Main River. The main stem Pawtuxet River originates at the confluence of the North and South Branches at River Point in West Warwick, Rhode Island. It then flows northeasterly between low banks for 10.9 miles to its mouth in Pawtuxet Cove. The river averages about 100 feet in width and about 4 feet in depth throughout its length and has an average slope, excluding drops at three existing run of river dams, of approximately 2.6 feet per mile. From its origin to the mouth the river has a total fall of about 50 feet. Originally, approximately 3 miles of the lower reach of the river was a tidal estuary until the construction of the Pawtuxet dam near the mouth of the river in 1870 to prevent salt water intrusion. In the lower reach the main river is joined by two other tributaries from the north, Meshanticut Brook and Pacasset River, at river miles 9.0 and 3.8, respectively. The river profile is shown on plate 2.

c. Tributaries.

(1) North Branch. The North Branch of the Pawtuxet River has a drainage area of 106 square miles and originates at Scituate Reservoir. Kent Dam, which forms the Scituate Reservoir, has a drainage area of 92.8 square miles. From the tailwater of the dam the river flows for 6.8 miles in a general southeasterly direction and falls

145 feet. In this reach, it flows through a succession of seven small run of river dams and pools to its junction with the South Branch at River Point. The river profile is shown on plate 3.

(2) South Branch. The South Branch of the Pawtuxet River, with a drainage area of 73.0 square miles, originates at Flat River Reservoir dam which has a drainage area of 56.7 square miles. From tailwater the river flows in a general northeasterly direction for 9 miles and falls 185 feet to its junction with the North Branch at River Point. Within this reach, the river meanders through marshes and a series of small storage ponds created by 11 mill dams. The river profile is shown on plate 3.

(3) Meshanticut Brook. Meshanticut Brook, with a drainage area of 15.0 square miles originates and flows generally southerly through the city of Cranston, Rhode Island to its confluence with the Pawtuxet at river mile 9.0. The river has a total length of about 6.5 miles and falls about 220 feet in the upper 2.9 mile reach and only 48 feet in its lower 3.6 mile reach. Development in the watershed varies from sparse in the upper basin to moderate in the lower basin.

(4) Pocasset River. The Pocasset River, with a drainage area of 20.8 square miles, originates in the town of Johnston and flows in a southeasterly direction through the city of Cranston, Rhode Island. In its 11.6 miles distance, it falls 275 feet to its junction

with the Pawtuxet River at river mile 3.8. In its course, the river falls 200 feet in its first 5-mile reach and 75 feet in its remaining length. The Pocasset River watershed is in the more highly developed areas of the Pawtuxet River basin. Pertinent data on the Pawtuxet River and its tributaries are given in table 1.

TABLE 1

PAWTUXET RIVER PERTINENT DATA

Name of Stream	Distance Above Pawtuxet Dam (river miles)	Total Drainage Area (sq. mi.)	Length (miles)
Pawtuxet River	0.0	230.4	10.9
Pocasset River	3.8	20.8	11.6
USGS Gage	4.5	200	-
Meshanticut Brook	9.0	15.0	6.5
North and South Branch Confluence	10.9	179.0	-
North Branch	10.9	106.0	6.8
Kent Dam (Scituate Reservoir)	17.7	92.8	
South Branch	10.9	73.0	9.0
Flat River Reservoir	19.9	56.7	

3. CLIMATOLOGY

a. General. The Pawtuxet River basin has a variable climate but, due to its proximity to Narragansett Bay, escapes the severity of cold and depth of snowfall experienced in the higher elevations of the interior areas of New England. It frequently experiences periods of heavy precipitation produced by local thunderstorms and by intense "lows" of tropical and extra-tropical origin that move northeasterly up the coast. The basin also lies in the path of the prevailing "westerlies" which generally travel across the country in an easterly or northeasterly direction producing frequent weather changes.

b. Temperature. The average annual temperature of the Pawtuxet River basin is about 50° Fahrenheit. Extremes in temperature range from occasional highs of 100°F. to lows of -15° Fahrenheit. Freezing temperatures may be expected from the latter part of October until the middle of April. The mean, maximum and minimum monthly and annual temperatures for the period of record at Providence are shown in table 2.

c. Precipitation. The mean annual precipitation over the Pawtuxet River basin varies from about 40 inches in the lower coastal areas to about 48 inches in the uplands. The distribution of the precipitation is quite uniform throughout the year. However, extremes in monthly values range from a high of more than 12 inches to less than 0.20 inch on several occasions. The monthly and annual precipitation at Providence, representative of the lower coastal area, are shown in table 2.

TABLE 2

MONTHLY TEMPERATURE-PRECIPITATION

AT PROVIDENCE, RHODE ISLAND

Month	Temperature 40 Years of Record			Precipitation 40 Years of Record		
	Mean	Maximum*	Minimum*	Mean	Maximum	Minimum
January	29.3	65	-9	3.59	7.12	0.50
February	29.3	65	-15	3.23	5.63	1.31
March	37.5	86	1	3.67	8.31	1.49
April	47.5	87	14	3.55	7.32	0.72
May	57.8	94	29	3.10	9.25	0.57
June	66.9	97	39	2.91	7.21	0.04
July	72.6	99	46	3.05	6.92	0.24
August	70.8	100	40	3.58	12.24	0.82
September	63.8	99	32	3.25	9.74	0.77
October	54.0	88	21	3.00	11.89	0.16
November	43.4	81	12	3.65	8.50	0.67
December	32.4	69	-11	3.74	10.75	0.58
ANNUAL	50.4	100	-15	40.32	58.57	25.44

*Based on 31 Years of Record 1940-1970

d. Snowfall. The average annual snowfall over the Pawtuxet River basin, shown in table 3, is about 40 inches. Water content of the snow cover usually reaches a maximum about the first of March but rarely exceeds 2 to 3 inches due to the moderating effect of Narragansett Bay.

TABLE 3

MEAN MONTHLY SNOWFALL

AT PROVIDENCE, RHODE ISLAND

Elevation 51 Feet MSL
40 Years of Record
(Depth in Inches)

Month	Snowfall
January	10.2
February	10.5
March	7.8
April	0.5
May	0
June	0
July	0
August	0
September	0
October	T
November	1.3
December	7.8

Annual Average 37.50 Inches

4. STREAMFLOW

The U.S. Geological Survey maintains six stream gaging stations within the Pawtuxet River watershed. Pertinent data for the six stations is summarized in table 4 and the locations of the stations are shown on plate 1. One of the stations is located on the main stem of the Pawtuxet at Cranston and a second, on the South Branch downstream of Flat River reservoir at Washington, Rhode Island. These two main river gages have both been in operation since about 1940. The remaining four gages are located on headwater tributaries.

Average annual runoff from the Pawtuxet watershed is about 27 inches or approximately 60 percent of average annual precipitation. Monthly runoff at the two main river gages is shown in table 5.

5. TIDES

a. General. Two high and two low tides occur each lunar day in the Narragansett Bay area with a mean high water of 2.47 feet msl and mean low water of -2.13 feet msl at Providence. Predicted tidal data are given for 16 locations in the Narragansett Bay area in the annual Tide Table Publication of the U.S. Department of Commerce, National Oceanic and Atmospheric Administration, entitled "Tide Tables, East Coast of North and South America".

b. Storm tides. The Pawtuxet dam, constructed at the mouth of the river in 1870 with a crest elevation of 5.3 feet msl, prevents

TABLE 4

GAGING STATION RECORDS
PAWTUXET RIVER WATERSHED

Gaging Station	Drainage Area (sq. mi.)	Period of Record	Discharge (cfs) Mean	Maximum*	Minimum
Misquitahawk Brook nr. No. Scituate, R.I.	3.06	1965-present	-	630	-
Nooseneck River at Nooseneck, R.I.	8.23	1963-present	14.9	318	0.81
Carr River at Nooseneck, R.I.	6.73	1963-present	9.1	221	0.30**
So. Br. Pawtuxet R. at Washington, R.I.	63.8	1940-present	126	1,860	2.8
Furnace Hill Brook at Cranston, R.I.	4.19	1965-present	-	586	0
Pawtuxet River at Cranston, R.I.	200	1939-present	393	3,110	22**

*Maximum recorded flow occurred 18 March 1968
**Minimum daily flow

TABLE 5

MONTHLY RUNOFF
(In Inches)

Month	Pawtuxet River at Cranston Rhode Island (D.A. = 200 square mile)			South Branch Pawtuxet River at Washington, Rhode Island (D.A. = 63.8 square mile)		
	Mean	Maximum	Minimum	Mean	Maximum	Minimum
January	2.98	6.56	0.78	2.83	5.84	0.69
February	3.15	7.38	1.34	3.02	4.54	1.33
March	4.57	7.47	2.56	4.25	6.64	2.66
April	3.86	7.01	1.24	3.83	6.49	1.22
May	2.65	5.38	1.34	2.81	5.61	1.24
June	1.40	3.96	0.24	1.61	4.37	0.49
July	0.77	2.52	0.002	0.94	2.29	0.28
August	0.78	3.43	0.06	0.88	2.81	0.29
September	0.86	4.96	0.11	0.91	4.16	0.28
October	1.09	6.48	0.20	1.21	5.81	0.45
November	2.01	5.74	0.43	1.97	5.85	0.50
December	2.81	5.99	0.67	2.77	5.63	0.66
ANNUAL	26.82	39.21	12.75	25.94	40.63	12.64

normal tides from affecting the lower Pawtuxet River; however, the dam is overtopped by abnormal storm tides. The lower Pawtuxet River is therefore subject to flooding from either fresh water flow or storm tides, or a combination of the two. The two greatest tides of record in recent years occurred as a result of hurricanes in September 1938 and August 1954. The maximum tidal level at Providence during these two events was 15.7 and 14.7 feet above msl, respectively.

c. Frequency of abnormal tides. The frequencies of abnormal tides in Narragansett Bay, in the vicinity of the mouth of the Pawtuxet River, were developed by the Corps of Engineers in 1960 in connection with the design of the Fox Point hurricane barrier at Providence. Tide frequencies were based on 26 years of continuous records plus historical accounts of earlier storm tides going back to the year 1635. The resulting tide frequency curve is shown on plate 4. Abnormal tide levels upstream of the Pawtuxet dam are generally about 2 feet lower then in the bay due to the hydraulic restriction posed by the dam. The project design hurricane tide for the Fox Point hurricane barrier, located just north of the mouth of the Pawtuxet River, was 20.5 feet above msl. It was concluded that a comparable storm tide upstream of Pawtuxet dam would be about 18.5 feet msl.

6. ANALYSIS OF FLOODS

a. General. The flood history of the Pawtuxet River demonstrates that major floods can occur any season of the year as a result of intense rainfall alone or in combination with snowmelt. Flat River and Scituate reservoirs exert control over 66 percent of the Pawtuxet watershed and Scituate in particular has a significant modifying effect on flood development in the Pawtuxet basin. Pertinent data on Scituate and Flat River reservoirs is listed in table 6. The magnitude of fresh water floods on the main stem Pawtuxet are a function of: (1) storm rainfall and resulting runoff from the 80.9 square miles of watershed downstream of the reservoirs and (2) the initial storage capacity in the reservoirs and the resulting magnitude and timing of discharges from the reservoirs. Floods are also produced on the lower Pawtuxet by abnormal tides in Narragansett Bay. Following are discussions of some of the more notable floods that have occurred in the 19th and 20th centuries.

b. Historic floods.

(1) 22-23 September 1815. An abnormally high tide of 14.2 feet above msl in the Providence area resulted in extensive coastal flooding. It is reported that vessels were driven from their moorings and many wharves, stores, houses and barns were destroyed. There was apparently a relatively insignificant amount of coincident rainfall-runoff associated with this storm. Though flooding was undoubtedly extensive in the lower Pawtuxet River, destruction was minimized by the lack of development in the flood plain at this date.

TABLE 6

SCITUATE AND FLAT RIVER RESERVOIRS
PERTINENT DATA

	Scituate	Flat River
Drainage Area (sq. mi.)	92.8	56.7
Spillway Length (feet)	412	169
Spillway Elevation (ft msl)	284	248
Top of Flashboards (ft msl)	285.5	N.A.*
Storage Capacity		
Spillway Crest (acre-feet)	113,600	5,150
Spillway Crest (inches)	23	1.7
Top of Flashboards (acre-feet)	118,500	N.A.*
Top of Flashboards (inches)	24	-
Surface Area at Spillway Crest (acres)	3,400	850
Top of Dam Elevation (ft msl)	298	256

*Not applicable

(2) 11-14 February 1886. This flood was the greatest ever known on the main stem Pawtuxet River, resulting from 7 to 8 inches of rainfall over the basin augmented by snowmelt with an estimated water equivalent of 2 inches. Experienced flood levels were 6 to 7 feet higher then any other known flood before or since this event. There were no record of flows on the main stem but previous studies by the Corps estimated the discharge of the river was about 14,000 cfs in the vicinity of the present USGS gage site in Cranston.

Scituate Reservoir was not in existence at the time of this flood. If it had been built and initially filled, it is estimated the resulting flood at Cranston would have been modified to about 11,000 cfs. A recurrence of such a flood today, with present levels of development in the lower basin would result in a catastrophic type disaster.

(3) 2-4 November 1927. The heaviest rainfall associated with this major storm system occurred outside the Pawtuxet basin. Rainfall amounts varying from 2 to 7 inches were reported within the watershed. Scituate Reservoir stored 100 percent of the runoff from its watershed and only a minor flood freshet developed in the lower basin.

(4) 9-21 March 1936. The New England floods resulting from this storm were caused by a combination of heavy rainfall, deep snow cover, and unusually high temperature for the season. Rainfall in

the Pawtuxet basin was about 3.4 inches for the period 9-12 March and 3.1 inches for the period 18-22 March. Water equivalent of the snow cover, which was depleted during the period, was estimated at about 1 inch.

The flood was significantly modified by storage capacity initially available in the upstream reservoirs and the resulting peak flow of the Pawtuxet River in the vicinity of the present USGS gage in Cranston was estimated at about 5,300 cfs.

(5) 18-24 July 1938. This flood was the greatest experienced on the main stem Pawtuxet since the construction of Scituate Reservoir in 1926. It was the result of a coastal storm producing an average of 7 inches of rainfall over the Pawtuxet basin. This event occurred at a time when both Flat River and Scituate reservoirs were initially almost full: therefore, the only modifying effect was that due to surcharge storage. The resulting peak discharge at Cranston has been estimated at about 6,300 cfs. The flow components making up the July 1938 flood hydrograph at Cranston are graphically presented on plate 6.

(6) 17-22 September 1938. The hurricane of September 1938 produced an abnormal tide level in Narragansett Bay of 15.7 feet above msl in the vicinity of the mouth of the Pawtuxet River. This tide was 10.2 feet above the crest of the Pawtuxet dam and resulted in extensive tidal flooding in the lower reaches of the Pawtuxet River. The

rainfall of the preceding four days averaged 5 inches over the Pawtuxet watershed, but upstream reservoir levels were low and Pawtuxet River flows were not considered a major contributor to experienced floods.

(7) 31 August 1954. Hurricane "Carol" passed over the western portion of the basin creating abnormally high tides to elevation 14.7 feet above msl in Narragansett Bay near the mouth of the Pawtuxet River. The overtopping of Pawtuxet dam resulted in flood stages to approximately 12.5 feet msl upstream of the dam. Wind gusts over 100 mph were recorded at Providence during this hurricane. Precipitation associated with this storm was only about 3 inches over the basin and fresh water flooding was not a major factor.

(8) 17-18 March 1968. The 1968 event was produced by 4 to 7 inches of rainfall occurring in a 48-hour period. A preceding storm on the 12th and 13th of the month plus some snowmelt provided high antecedent runoff conditions. The resulting peak discharge at the USGS gage in Cranston was 3,110 cfs which was the greatest flow recorded since establishment of the gage in 1939. Though flood damages were not major, the event occurred following a period of very intensive development in the lower basin, and brought attention to the great flood damage potential to which most of this development was exposed. The 1968 flood discharge on the main stem Pawtuxet River was significantly modified by storage capacity initially available at Scituate Reservoir.

Had this reservoir been initially filled it is estimated the peak flow at Cranston would have been about 6,500 cfs or comparable to the experienced July 1938 flood when reservoirs were initially full.

Detailed analysis of the development of the March 1968 flood is graphically presented on plate 5. Pertinent data on the effects of Scituate and Flat River Reservoirs on historic floods is summarized in tables 7 and 8.

7. FLOOD FREQUENCIES

a. General. Flood frequencies for the Pawtuxet River were derived through analysis of historical flood discharge data within the basin, both recorded and computed, as well as by comparison with long term discharge records of streams outside the basin but in the general region. Peak discharge frequency curves were developed for (1) the Pawtuxet River at Cranston, (2) the South Branch at Washington (3) the uncontrolled 50.5 square mile local area downstream of the Flat River and Scituate Reservoirs to the Cranston gage and (4) the 30.4 local from the gage to the mouth of the river.

b. Pawtuxet River. Because of the complexity of the effect of upstream reservoirs on floodflows on the main stem Pawtuxet, conventional statistical flood frequency analysis of the data was not considered applicable. Instead, recorded annual peak flows and historical flood peaks were plotted using "Beard's" plotting positions and a

TABLE 7

FLOOD STORAGE BY UPSTREAM RESERVOIRS

	Scituate Reservoir (D.A. = 92.8 sq. mi.)				Flat River Reservoir (D.A. = 56.7 sq. mi.)			
	Initial Storage Capacity		Surcharge Storage		Initial Storage Capacity		Surcharge Storage	
	Inches	%Runoff	Inches	%Runoff	Inches	%Runoff	Inches	%Runoff
February 1886	Before Construction				0.48	10	1.51	30
November 1927	3.72	100	0	0	1.06	30	0.27	7
March 1936	3.21	60	1.47	28	0	0	0.76	14
July 1938	0	0	1.30	37	0.11	5	0.43	19
March 1968	2.24	100	negligible	negligible	0	0	.81	38

TABLE 8

ESTIMATED EFFECT OF UPSTREAM RESERVOIRS ON PEAK FLOWS AT CRANSTON, RHODE ISLAND

Flood	Flat River & Scituate Initially Filled To Spillway Crest (cfs)	With Complete Storage In Flat River And Scituate (cfs)	Experienced Discharge (cfs)
February 1886	11,000	7,000	14,000*
July 1938	6,300	3,300	6,300
March 1968	6,800	2,700	3,110
SPF	19,000	13,000	-

*Scituate Reservoir not in existence

composite frequency curve was fitted to the plotted data as shown on plate 7.

c. South Branch. A discharge frequency curve for the South Branch at Washington, Rhode Island was developed by statistical analysis using the annual peak flows for 33 years of record, plus the addition of the estimated peak flows for the 1936 through 1938 water years. Thus the analysis was made using 36 annual peak flows. A Log Pearson type analysis was made in accordance with procedures presented in "Statistical Methods in Hydrology" by L. Beard dated January 1962. The basic statistical data is listed in table 9.

d. Locals. The peak discharge frequency curves for the unmodified 50.5 square mile local downstream of Flat River and Scituate Reservoirs and the 30.4 square mile local downstream of the gage were developed by relating the computed 1968 flood contributions from the areas with similar gaged watersheds, namely Kettle Brook and Branch River in the neighboring Blackstone River basin. Statistical data developed for the gaged streams and that adopted for the local watersheds are listed in table 9. The adopted discharge frequency curve for the Pawtuxet River at Cranston is shown on plate 7.

e. Flood stage frequencies. Flood stage-frequency curves, for use in damage-benefit analyses, were developed at various index stations using the discharge frequency information just discussed in conjunction

TABLE 9

DISCHARGE FREQUENCY DATA

	South Branch Pawtuxet River Washington, R.I.	Branch River Blackstone Basin Forestdale, R.I.	Kettle Brook Blackstone Basin Worcester, Mass.	Adopted for Local To Cranston Gage	Adopted for Local Below Cranston
Drainage Area (sq. mi).	63.8	91.2	31.3	50.5	30.4
Log of Mean	2.81	3.19	2.65	3.05	2.82
Standard Deviation	0.216	0.220	0.325	0.270	0.250
Adopted Skew	+0.5	+0.5	+0.5	+0.50	+0.50
100-Year Frequency (Q in cfs)	2,750	6,600	3,620	6,000	3,000
50-Year Frequency "	2,200	5,300	2,690	4,600	2,500
20-Year Frequency "	1,600	3,950	1,790	3,300	1,800
10-Year Frequency "	1,300	3,100	1,270	2,500	1,400
5-Year Frequency "	950	2,400	850	1,800	1,050
2-Year Frequency "	620	1,480	420	1,100	640

with developed stage-discharge rating curves. The rating curves were developed from backwater studies which are discussed under section 9, entitled, Flood Profiles. In the reach of the river affected by flood tides, composite stage frequency curves were developed reflecting tide and fresh water flooding. For example if a given flood level was expected to be reached 10 times in 100 years by fresh water flooding and 5 times per 100 years by flood tides then the composite curve would indicate flooding to this level 15 times per 100 years.

Modified stage frequency curves for various plans of improvement were similarly developed using the modified discharge frequencies and appropriate rating curves.

f. Effect of future urbanization. In allowing for future development in the watershed it was estimated that flood discharge frequencies would increase 10 percent between the present and 1990 and another 10 percent between 1990 and 2020. Such an estimate cannot be precise but was based on interrelations in New England between population density and land use, land use and percent impervious cover, and percent change in impervious cover and percent change in peak runoff. A Treatise on this subject entitled, "Effect of Urbanization on Peak Runoff" was prepared by the New England Division in June 1973 in connection with a South Eastern New England regional study. Reference is also made to "Effects of Watershed Changes on Streamflow," Water Resources Symposium No. 2, University of Texas Press, 1969.

Population projections for the region were developed in 1972 by the Bureau of Economic Analysis of the U.S. Department of Commerce. Based on this data it is projected that the population density in the Pawtuxet basin will increase from 315 per square mile in 1970 to 540 per square mile in 1990. This growth is expected to result in a 50 percent increase in impervious cover from about 8 to 12 percent and result in a 10 percent increase in peak discharge. At least a comparable percent increase is expected between 1990 and 2020.

8. STANDARD PROJECT FLOOD

a. General. The standard project flood (SPF) represents the flood discharge that may be expected from the most severe combination of meteorologic and hydrologic conditions that are considered reasonably characteristic of the region, excluding extremely rare combinations. The SPF represents a "standard" against which the flood potential of a river can be judged, as contrasted to an analysis of flood records which may be misleading due to abnormal sequences of events during the period of record. The SPF for the Pawtuxet River was developed using standard project storm rainfall, as described in EM 1110-2-1411, and unit hydrographs derived from analysis of recorded floods in the basin.

b. Rainfall. The standard project storm was oriented over the Pawtuxet watershed with its center near the junction of the two branches with its long axis running in a southwest to northeast direction. The storm pattern is shown on plate 8.

The standard project storm index rainfall for 24 hours over a 200 square mile area is 11 inches. A summary of the adopted standrad project storm contribution for a drainage area of 200 square miles is as follows:

	Inches
SPS Rainfall (24 hrs)	11.0
Losses	2.3
Rainfall Excess	8.7
Maximum 3-Hour Rainfall Excess	5.3

Losses were assumed at the rate of 0.1 inch per hour which is consistant with minimum losses determined in previous Corps of Engineer studies for the New England area. The rainfall over each tributary and local area was obtained by planimetering between the isohyets and respective watershed divides.

c. Unit hydrographs. Unit hydrographs were derived, through analysis of the March 1968 flood, for the watersheds of (1) Flat River Reservoir, (2) Scituate Reservoir and (3) the two downstream local areas. The peaks of all developed unit hydrographs were increased 25 percent, in accordance with EM 1110-2-1405, to reflect the increased runoff rates expected under standard project storm conditions. A typical unit hydrograph development is shown on plate 5.

d. Standard project flood. Rainfall excess was computed for each subwatershed and applied to the adopted unit hydrographs. The resulting hydrographs for Flat River and Scituate Reservoirs were routed through surcharge storage assuming the reservoirs initially filled to spillway crest. The resulting outflow hydrographs were then routed downstream and combined with the component hydrographs from the local areas. The development of the SPF for the Pawtuxet basin is graphically illustrated on plate 8.

9. FLOOD PROFILES

Flood profiles for the mainstem of the Pawtuxet River are shown on plate 2. Profiles were computed by standard backwater procedures using a minimum of surveyed cross sections of the river and the computer program, HEC-2, developed by the Hydrologic Engineering Center in Davis, California. The computer model was calibrated, to the extent possible, against historic flood elevations. In many instances the computed profile for a historic flood discharge was somewhat higher than observed and this was attributed largely to reduced hydraulic capacity of the river due to accelerated development. Backwater computations were made for a range of both natural and modified floods using a Manning's n of 0.05 for channel and 0.08 for overbank. Assumed contraction and expansion loss coefficients were 0.3 and 0.5, respectively.

10. NATICK DIVERSION

a. General. The Natick Diversion, as part of a flood system for the main stem Pawtuxet River, would divert floodflows from the Pawtuxet River at Natick (river mile 9.75) via deep rock tunnel to Apponaug Cove, a distance of about 13,000 feet. Plans and profiles of the diversion structures are shown on plates 9 through 12. Hydrologic engineering features of the various components of the proposed diversion are discussed in the following paragraphs. Hydraulic analysis made during plan formulation was general in scope. More detailed analysis, probably including model studies of some of the more complex hydraulic structures, will be required in final design.

b. Diversion tunnel. The tunnel will be 30 feet in diameter and approximately 13,000 feet long. Depending on quality of rock the tunnel will be either concrete-lined or smooth-bore unlined with a hydraulic roughness comparable to concrete. The invert of the tunnel at the upstream end will be -75 feet msl and will slope at 0.0104 feet per foot to elevation -210 feet msl at the outlet. With the design discharge of 13,000 cfs the velocity of flow in the tunnel will be 18 feet per second. The hydraulic capacity of the tunnel was computed using a Manning's "n" of 0.015.

c. Diversion inlet. The inlet to the tunnel will be a "morning glory" type spillway atop a 30-foot diameter vertical shaft. The inlet will be located in the Pawtuxet River just downstream of the existing Natick dam. The lip of the morning glory with a circumference of 121.9 feet will be at elevation 38 feet msl approximately 10 feet above the existing riverbed. Regulation of flows to the diversion will be accomplished by the construction of a regulating dam just downstream of the inlet. This dam will contain two 8x8 foot regulating gates and a 115 foot long emergency overflow weir at elevation 48.0 feet msl. The gated outlets will permit passage of normal riverflows. Closing the gates will cause the water rise and enter the inlet to the diversion tunnel. Throttling the gates will allow the diversion to be self regulating for Pawtuxet River flood control. The lip of the morning glory spillway will be a hydrualic control for flows up to approximately 12,000 cfs, with a required head pool elevation at the inlet of about 43.5 feet msl. With flows greater then approximately 12,000 cfs the inlet will become submerged by tunnel backwater and the hydraulic control will switch to the tunnel outlet. With the head pool at elevation 48 feet msl, the diversion will be capable of discharging 13,000 cfs for all tides up to about +10 feet msl. Approximately 11,000 cfs could be diverted with a tide as high as 20 feet above msl. Plans of the inlet are shown on plates 10 through 12.

d. Diversion outlet. The outlet of the diversion tunnel will consist of a 30-foot diameter vertical shaft transitioning to a 114-foot long horizontal apron. A plan and profile of the outlet is shown on plates 11 and 12. The outlet end sill will be at elevation -4 feet msl and equipped with stop log piers to permit evacuation of the tunnel if necessary. Under design discharge conditions, and for all tides below approximately +10 feet msl, the 90-foot clear span between the piers on the end sill will be the hydraulic control. Flows exiting the outlet are directed away from shore towards the existing Federal navigation channel. An apron of riprap will be placed at the outlet exit to prevent excessive scour from diversions during periods of low tide. With a design flow of 13,000 cfs the velocity in the vertical shaft will be approximately 18 feet per second. Water surface at the top of the shaft would rise to near the energy gradient of +10.0 feet msl and then drop to about critical depth elevation of +6 feet msl through the piers on the outlet sill. Critical depth and velocities through the piers on the end sill, with a flow of 13,000 would be approximately 9 feet and 18 feet per second, respectively. Head loss through the outlet structure, including one velocity head, was estimated to be approximately 7 feet.

e. Apponaug Cove. Outlet discharges from the diversion tunnel will flow through Apponaug Cove a distance of approximately 4,500 feet to the ocean. Hydraulic head loss and velocities through the cove would be a maximum with diversion during low tide. Hydraulic head loss and maximum velocity in the navigation channel through the cove for different tides and diversion rates are listed in table 10.

f. Effects of Diversion. The effects of the Natick diversion on downstream flooding on the Pawtuxet River is summarized in table 11.

TABLE 10

APPONAUG COVE HYDRAULICS

Tide Level (ft msl)	Diversion Rate (cfs)	Head Loss in Cove (ft)	Maximum Velocity in Channel (ft/sec)
Mean low water	13,000	3.0	8.0
-1.9	8,000	1.5	5.5
	3,000	0.4	2.3
Spring tide			
+3.6	13,000	0.4	4.4
	8,000	0.2	2.7
	3,000	Negligible	1.0
10-year frequency tide			
+8.6	13,000	0.2	2.7
	8,000	Negligible	1.5
	3,000	Negligible	0.6

TABLE 11

EFFECTS OF NATICK DIVERSION

Location	Drainage Area (sq. mi.)	March 1968 Flood				July 1938 Flood			
		Natural		Modified		Natural		Modified	
		Q (cfs)	Elevation (feet msl)	Q (cfs)	Elevation (feet msl)	Q (cfs)	Elevation (feet msl)	Q (cfs)	Elevation (feet msl)
Pawtuxet River at Natick Diversion	180	2,600	33.4	-	28.0	5,800	37.6	-	28.0
At Cranston USGS Gage	200.0	3,110	19.7	800	17.3	6,300	22.7	800	17.3
At Warwick Avenue	228	3,900	12.0	2,000	9.7	6,800	14.3	2,100	9.8

Location	Drainage Area (sq. mi.)	100-Year Frequency Flood				Standard Project Flood			
		Natural		Modified		Natural		Modified	
		Q (cfs)	Elevation (feet msl)	Q (cfs)	Elevation (feet msl)	Q (cfs)	Elevation (feet msl)	Q (cfs)	Elevation (feet msl)
At Natick Diversion	180	5,500	37.4	-	30.6	17,000	46.9	4,000	35.4
At Cranston USGS Gage	200.0	6,600	23.0	2,300	20.8	19,600	32.8	4,700	25.6
At Warwick Avenue	228	8,200	15.2	5,400	13.6*	23,000	21.3	12,800	18.6*

*Tidal Flood Level

Flood levels would be generally reduced from 3 to 6 feet and the standard project flood would be reduced generally from 5 to 10 feet. Modified flood profiles are shown on plate 2. Modified flood stages and frequencies downstream of the diversion are a function of (1) hurricane tides, (2) runoff from the downstream uncontrolled watershed area, and (3) some spillage at the diversion during the rarest of floods. The modified profiles were determined by backwater computations using the modified flood discharges.

11. WARWICK LOCAL PROTECTION (Warwick Ave Area)

a. General. As previously discussed, properties on the Pawtuxet River flood plain near the mouth of the river are susceptible to flooding from either abnormal tides in Narraganset Bay or fresh water flows of the river. The Natick diversion will greatly reduce the frequency and magnitude of fresh water flooding but the Warwick Ave Area Local Protection Project is required to protect the Warwick Industrial Park against residual tidal and fresh water flooding. The project consists of about 6,000 linear feet of dikes and walls, 2 street opening structures, approximately 1,000 feet of channel relocation, and two pumping stations for removal of interior drainage. The project will provide protection to approximately 150 acres of industrial and commercial areas.

b. Design Flood Criteria. The dikes and walls were designed to protect against the severest of the following criteria: (a) a modified standard project flood on the river coincident with a 100-year frequency tide in the bay and (b) a standard project tide in Narraganset Bay. A general plan of the project is shown on Plate 13.

The design tide levels upstream of the Pawtuxet dam were reduced 2 feet from those in Narraganset Bay to reflect the modifying effect of the dam as was discussed in Section 5c. The standard project and 100-year frequency tides in the bay are 20.5 and 16 feet msl, respectively; therefore, comparable levels upstream of the dam are 18.5 and 14 feet msl, respectively. The governing criteria for the dikes and walls were, for the most part, the standard project tide level of 18.5 feet msl. The design flood level for the project varied from 18.5 feet msl at the downstream end of the protection to 22 feet msl at the upstream end. Design flood profiles are shown on plates 14 and 15.

c. Freeboard. Freeboard is defined as the vertical distance measured from the design water surface to the top of dike or wall. Freeboard is provided to ensure that the desired degree of protection will not be reduced by unaccounted factors.

The dikes and concrete walls for the Warwick Ave area local protection were designed to provide 3 and 2 feet of freeboard, respectively. Less freeboard is provided with concrete walls due to their greater resistance to failure if some overtopping were to occur. Building walls slightly lower than the dikes also permit overtopping of walls before dikes; thereby serving as a relief valve in the event of a flood greater than design.

d. Velocities. Maximum flow velocities in the river channel along the line of protection would occur during high flows in the river and normal tides in the bay. Maximum velocities with a modified standard project discharge of 12,800 cfs would range from 5 to 7 feet per second. The riverside slopes of the protective dikes will be protected by riprap designed to withstand the tractive forces that would be produced by the modified design flood.

e. Effect of project on river hydraulics. During flood periods when dishcarges and stages in streams are increasing, those flows entering flood plain areas are temporarily stored until the recession period of the flood. The effect of this temporary storage is, to lag and reduce the flood peak as it progresses downstream. When flood plain storage is lost by the building of dikes, the flows that would normally enter the storage areas must either move into adjoining storage areas or move on through the reach causing increased flood discharges downstream, at least during the rising period of the flood. Historically flood stages on the lower Pawtuxet River have risen at rates up to one-sixth foot per hour. The two local protection projects will remove approximately 200 acres of flood plain, therefore, this rate of rise of water over the protected area would represent a flow rate of 400 cfs. Using the above analogy it was concluded that peak discharges would not be increased more than 5 percent by the dikes and since the diversion will reduce flows by approximately 50 percent in the area of the dikes, the net effect of both the diversion and local protective dikes would be at least a 45 percent reduction in flows.

f. Interior Drainage.

(1) General. The line of protection of the Warwick Ave area LPP will intercept the runoff from approximately 710 acres of interior area. Gravity outlets, a collector drain, pressure conduit and a pumping station are included as an integral part of the project for conveying interior drainage to the river.

(2) Drainage Areas. The total 710 acres of interior area can best be analyzed as 3 subareas. Subarea 1 is a 110 acre area located upstream of Warwick Avenue extending to the upper end of the project. This area is mostly residential with an average slope of about 2 percent draining to the highly industrial and very flat area lying right along the river. Subarea 2, 150 acres in size, is generally outlined by Warwick Avenue on the west, Boston Post Road on the south and the Pawtuxet River on the northeast. This area is extremely flat having practically no drainage relief. The one existing open channel drain passing through serves much of the area.

Subarea 3, an independent 450 acres of watershed lying south of Boston Post Road, is drained by an unnamed brook and outleting to the Pawtuxet River near the downstream end of the proposed line of protection. Subarea 3 is long and narrow with an average slope of about 0.6 percent. There are two natural ponds in the upper part of this watershed which serve to retard runoff from short duration high intensity storms.

Delineation of the subareas is shown on plate 13 .

Estimated 10- and 100-year frequency discharges for the subareas are listed below. Discharge values were computed by multiplying the discharge frequencies developed for the entire local area below the Cranston gage by the ratio of contributing drainage area taken to the 0.7 power. The computed discharge frequencies compared favorably with results obtained using methods presented in: "Flood Magnitude and Frequency of Massachusetts Streams," Open-File Report Number 84-131, U.S. Department of the Interior, Geological Survey, March 1974.

	Subarea 1	Subarea 2	Subarea 3
Drainage Area (acres)	110	150	450
10 Year Q (cfs)	37	46	100
100 Year Q (cfs)	80	100	214

It is noted that the discharge frequencies represent estimated runoff from a watershed with widespread shallow puddling during intense rainfall. This condition currently exists and will presumably exist in the future due to the minimal drainage relief in the area. This shallow ponding will be restricted to parking lots and undeveloped areas in the future through proper zoning.

(3) Site limitations. The elevation of most of the land along the land side of the dikes and walls is very low relative to

the normal level of the Pawtuxet River. The normal level of the river is about +5 feet msl and most of the land is between elevations 8 and 10 feet msl. This site limitation makes impractical the installation of large underground collector drains. Such drains would remain filled with water without continuous and costly pumping. For this reason it is planned to provide a shallow trapezoidal channel section along the land side of the dike which will serve both as a temporary detention area and a means of conveying flows to one centrally located pumping station. It will be specified in the local assurances that no building be allowed in the protected area with first floor grades below elevation 12.0 feet msl.

(4) Gravity outlets. Gravity outlets will be provided through the line of protection capable of discharging the peak 100-year frequency runoff with a normal river stage.

(5) Warwick Ave Area pumping Station #1. Warwick pumping station #1 will be designed to discharge the 10-year frequency interior runoff against a design river stage. The pumping station will have a design capacity of 80 cfs, the 10-year peak runoff from subareas 1 and 2.

(6) Warwick Ave Area pumping station #2. Subarea 3 will normally discharge by gravity to the river through a gated outlet in the line of protection at a site near its present outlet. However, pumping station #2 will be provided at the site so that during hurricant tides the

gravity outlet can be closed and the interior runoff can be pumped. The gravity outlet will be designed to discharge the 100-year frequency discharge of 210 cfs with a normal river stage. Pumping station #2 will be designed with a 10-year frequency peak runoff capacity of 100 cfs.

A pressure conduit system in lieu of a pumping station for subarea 3 was investigated but was found to provide small savings in cost. Further interior drainage analysis will be performed during detailed design.

12. WARWICK LOCAL PROTECTION (Elmwood Ave Area)

a. General. The Elmwood Ave Area Local Protection Project will be built to protect approximately 43 acres of mostly residential property from residual Pawtuxet River flooding. The project will consist of about 4,700 linear feet of dike, 400 feet of wall, and interior drainage facilities including one pumping station. A plan of the project is shown on plate 16.

b. Design Flood. The project will be designed to provide three feet of freeboard above the standard project flood level of the Pawtuxet River as modified by the proposed upstream Natick diversion. Height of protection will vary from elevation 26 feet mean sea level at the downstream end of the dike to elevation 27 feet mean sea level at the upstream end. Design profiles are shown on plate 17. The modified

SPF discharge at the project site is 12,000 cfs.

c. Velocities. Maximum velocities in the river channel along the line of protection with a modified SPF discharge would range from three to five feet per second. The riverside slopes of the protective dikes will be protected by rip rap designed to withstand the tractive forces produced by the design flood.

d. Effects of Project on River Hydraulics. For information on the effects of the Elmwood Ave area project on the hydraulics of the Pawtuxet River, reference is made to paragraph 11e.

e. Interior Drainage. The dikes and walls at the Elmwood Ave Area LPP will intercept runoff from a total of approximately 150 acres of interior area. No detailed analysis was made for interior drainage, but for costing purposes it was assumed that drainage from the upper 85 acres of area lying south of 2nd Avenue would be discharged to the river through a 48-inch diameter pressure conduit, and a pumping station would be provided for the remaining lower 65 acres of interior area. The pumping station and pressure conduit were designed to pass a 10 year storm runoff against the design river stage, resulting in design capacities of 105 and 135 cfs, respectively. Gravity drains through the dike were designed to discharge the 100 year storm runoff with a normal river stage. Discharges were computed using the Rational formula with a coefficient of 0.5 and a time of concentration of 30 minutes. More detailed analysis of interior drainage will be required during final design.

13. PAWTUXET RIVER WATER QUALITY

The Pawtuxet River is an intrastate stream that has been assigned a B classification by the state of Rhode Island. State prescribed standards for Class B water designate that it shall have good aesthetic quality and that it be suitable for water supply with appropriate treatment, waterborne recreation, fish and wildlife habitat, agricultural usages, industrial processes and cooling.

Class B water quality standards require that the dissolved oxygen concentration be a minimum of 5 mg/l at any time and at least 75 percent saturated for 16 hours/day. Coliform bacteria are not to exceed a median value of 1,000 colonies/100 ml nor more than 2,400 in more than 20 percent of the samples collected. These waters are also to be free from concentrations of chemical constituents and radioactive material which would be harmful to human, animal or aquatic life. The pH range is always to be within 6.5 to 8.0 standard units and any increases in temperature, color, turbidity, taste and odor will be such that they will not impair any of the above mentioned usages.

The quality of water for a prescribed distance downstream from waste treatment facilities, until complete mixing is accomplished, does not affect the usage class adopted.

The New England Division initiated a water quality sampling program in the Pawtuxet River basin during September 1975. The purspose of the program was to develop a data base with which to evaluate the water quality effects of the proposed diversion of flood waters from the Pawtuxet River on the marine environment of Apponaug Cove and Greenwich Bay, Rhode Island. Two sampling stations were located on the main stream Pawtuxet River and one each on the North Branch and South Branch tributaries. Collection and analysis of the samples was performed for the Corps by the U.S. Environmental Protection Agency laboratories in Kingston, Rhode Island and Needham, Massachusetts. The water quality data for each of the stations are presented on tables 12 through 15.

Evaluation of these data indicates that the quality of water measured during the nine month sampling program does not meet the prescribed state stream standards. However, it is expected that implementation of the State of Rhode Island's pollution abatement program will produce acceptable water quality levels by 1983, as required by federal Public Law 92-500.

TABLE 12

PAWTUXET RIVER
WATER QUALITY DATA
STATION 1: BROAD STREET, CRANSTON

Date	Average Daily Flow* (cfs)	Air Temp. (°C)	Water Temp. (°C)	pH (su)	pH Paper	Dissolved Oxygen (mg/l)	Total Coliform Bacteria (/100 ml)	Fecal Coliform Bacteria (/100 ml)	NH_3-N (mg/l)	COD (mg/l)	Total Nonflt. Residue (mg/l)	Volatile Nonfiltr. Residue (mg/l)	Fixed Nonfiltr. Residue (mg/l)	BOD 5-Day (mg/l)	BOD 20-Day (mg/l)
(1975)															
16 Sep	137	19	18	6.0	6.0	7.0	92,000	1,700	2.00	37	8	4	4	J12.8**	22.3**
25 Sep	679	11	16	5.7	-	-	70,000	3,300	0.40					6.6**	12.4**
2 Oct	263	19.5	18.5	6.9	-	7.7	5,400	1,700	1.15	28	9	6	2	J5.9	15.4**
30 Oct	335	16	14	6.9		9.0	92,000	54,000	K0.10	24	3	3	K1	5.2	6.6**
18 Nov	506	17	11	7.0	-	9.2	1,700	460	0.65	27	5	4	2	J5.5	10.8**
9 Dec	570	-	-	-	-	-	9,200	330	0.45	22	5	4	1	J4.5	9.2
(1976)															
20 Jan	854	-1	3	7.5		13.8	5,400	270	0.45	16	1	1	K1	J2**	J6
2 Feb	1690	1.7	4	7.35		14.0	24,000	7,900						-	-
24 Feb	774	10	6	7.6		12.3	13,000	170	0.46	20	4	2	2	J6	11.5**
29 Mar	295	15.0	10.0	6.3		10.6	26,000	260							
28 Apr	297						9,400	1,300							
27 May	217	22	14.5	6.1			1,300	130							
7 Jun	no record	28	17.5	7.05			1,300	330							

*Average daily flow at Cranston Gage, Pawtuxet River (PROVISIONAL)
**Average of two values
K = less than J = estimated

TABLE 13

PAWTUXET RIVER
WATER QUALITY DATA
STATION 2: PROVIDENCE STREET, WEST WARWICK

Date	Average Daily Flow* (cfs)	Air Temp. (°C)	Water Temp. (°C)	pH (su)	pH Paper	Dissolved Oxygen (mg/l)	Total Coliform Bacteria (/100 ml)	Fecal Coliform Bacteria (/100 ml)	NH_3-N (mg/l)	COD (mg/l)	Total Nonfltr. Residue (mg/l)	Volatile Nonfiltr. Residue (mg/l)	Fixed Nonfiltr. Redisue (mg/l)	BOD 5-Day (mg/l)	BOD 20-Day (mg/l)
(1975)															
16 Sep	137	19	18	6.3	6.0	7.7	>160,000	2,600	0.80	17	10	3	7	J3.5	6.5**
25 Sep	679	11	15	6.7	-	-	49,000	7,900	0.15					5.5**	8.4**
2 Oct	263	20	18.5	6.9	-	7.7	35,000	4,600	0.25	19	3	2	1	J1.8	6.6**
30 Oct	335	16	15	6.8		8.2	>240,000	35,000	K0.10	58	6	4	1	29.8**	39.6**
18 Nov	506	17	11	7.4		9.0	35,000	1,300	0.07	18	3	2	K1	J1.8	3.9**
9 Dec	570	-	-	-		-	3,500	490	K0.05	10	2	2	K1	J2.	4.1**
(1976)															
20 Jan	854	-1.	3.2	5.25		13.8	3,500	1,100	K0.05	15	27	4	23	J2**	J4
2 Feb	1,690	0.6	3.0	6.8		14.0	92,000	7,000						-	-
24 Feb	774	10.	5.	7.65		12.2	2,400	790	0.14	9	2	1	1	J1.8	4.5**
29 Mar	295	16.0	10.2	6.7		11.0	35,000	4,900							
28 Apr	297						14,000	7,000							
27 May	217	21.	14.5	6.5			6,400	2,700							
7 Jun	no record	27.5	17.5	6.7			9,400	1,700							

*Average daily flow at Cranston Gage, Pawtuxet River (PROVISIONAL)
**Average of two values
K = less than J = estimated

TABLE 14

PAWTUXET RIVER
WATER QUALITY DATA
STATION 3: ROUTE 33, WEST WARWICK
SOUTH BRANCH, PAWTUXET RIVER

Date	Average Daily Flow* (cfs)	Air Temp. (°C)	Water Temp. (°C)	pH (su)	pH Paper	Dissolved Oxygen (mg/l)	Total Coliform Bacteria (/100 ml)	Fecal Coliform Bacteria (/100 ml)	NH_3-N (mg/l)	COD (mg/l)	Total Nonfiltr. Residue (mg/l)	Volatile Nonfiltr. Residue (mg/l)	Fixed Nonfiltr. Residue (mg/l)	BOD 5-Day (mg/l)	BOD 20-Day (mg/l)
(1975)															
16 Sep	137	19	17.5	5.95	6.0	8.8	35,000	4,900	0.70	31	6	4	3	J15.9**	20.9**
25 Sep	679	11	15.0	6.4	-	-	230,000	49,000	0.20					3.9	8.0**
2 Oct	263	19	19	6.4	-	6.6	>160,000	>160,000	0.25	46	3	2	1	J16.2**	24.0**
30 Oct	335	16	15	7.5		8.5	13,000	13,000	K0.10	27	10	6	4	12.2	15.2**
18 Nov	506	17	11	7.2		12.1	23,000	7,000	0.08	37	4	3	K1	J9.9**	15.3**
9 Dec	570	-	-	-		-	22,000	4,900	0.05	39	4	4	K1	J10.5**	14.2**
(1976)															
20 Jan	854	-1.	3.2	5.2		13.8	9,200	700	0.06	27	2	2	1	J11.5**	J16
2 Feb	1,690	-0.6	3.0	7.5		16.0	350,000	9,400						-	-
24 Feb	774	10.0	6.0	6.5		11.0	280,000	620	0.26	27	2	1	1	J9.8	16**
29 Mar	295	16.0	10.0	6.9		10.4	540,000	49,000							
28 Apr	297						160,000	13,000							
27 May	217	20.	16.0	6.3			54,000	17,000							
7 Jun	no record	27.	17.	.95			11,000	1,300							

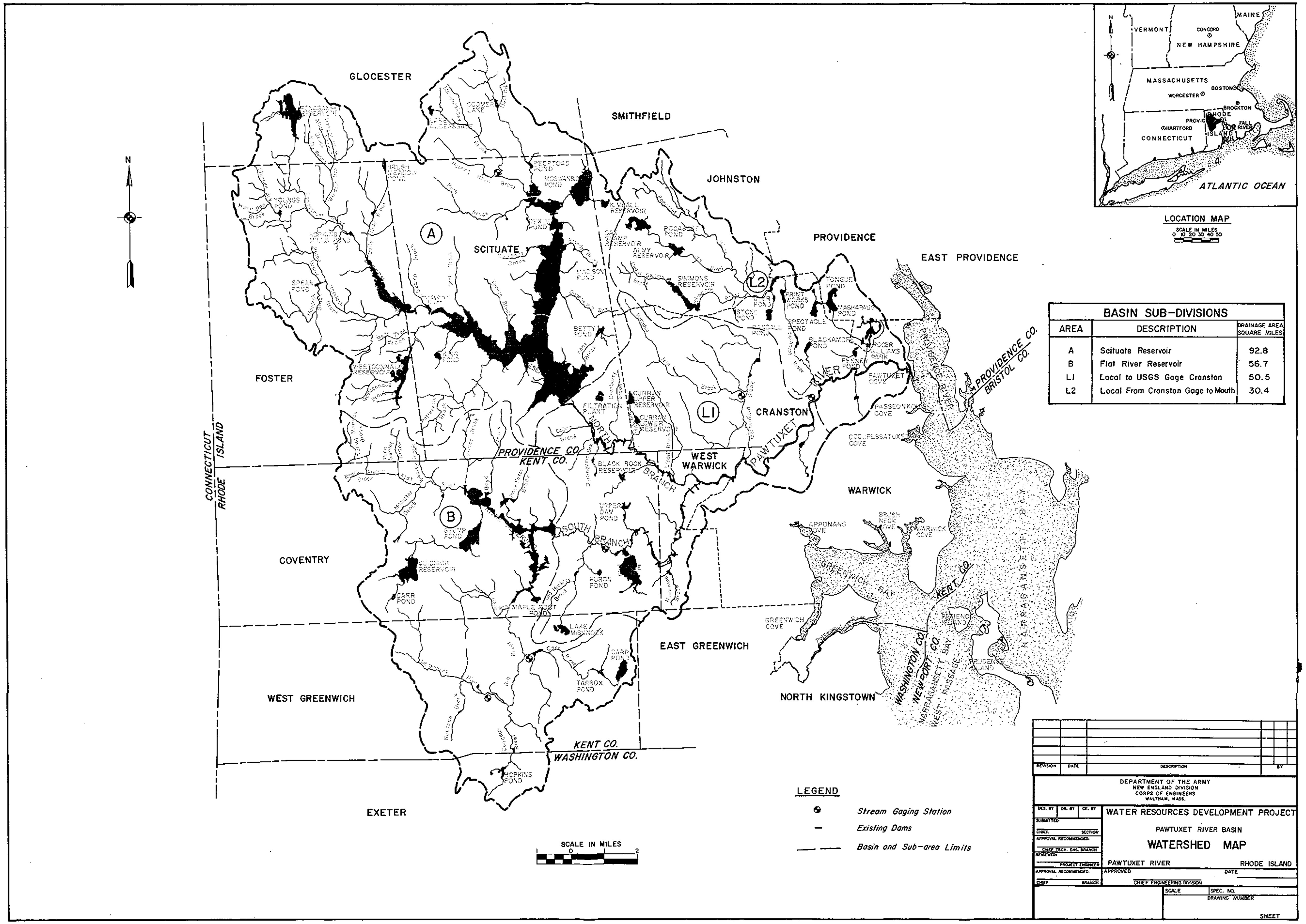
*Average daily flow at Cranston Gage, Pawtuxet River (PROVISIONAL)
**Averate of two values
K = less than J = estimated

TABLE 15

PAWTUXET RIVER
WATER QUALITY DATA
STATION 4: ROUTE 115, WEST WARWICK
NORTH BRANCH, PAWTUXET RIVER

Date	Average Daily Flow* (cfs)	Air Temp. (°C)	Water Temp. (°C)	pH (su)	pH Paper	Dissolved Oxygen (mg/l)	Total Coliform Bacteria (/100 ml)	Fecal Coliform Bacteria (/100 ml)	NH_3-N (mg/l)	COD (mg/l)	Total Nonfiltr. Residue (mg/l)	Volatile Nonfiltr. Residue (mg/l)	Fixed Nonfiltr. Residue (mg/l)	BOD 5-Day (mg/l)	BOD 20-Day (mg/l)
(1975)															
16 Sep	137	19.5	18	6.0	6.5	9.0	160,000	3,900	0.6	5	6	1	4	J1.6	3.8**
25 Sep	679	11.0	15.5	6.6	-	-	49,000	2,300	0.90					5.1	8.6**
2 Oct	263	20	18	6.7	-	9.2	5,400	490	K0.10	10	1	1	K1	J2.3	4.3**
30 Oct	335	16	15	6.9		9.9	35,000	4,600	J0.85	34	10	5	5	3.8**	7.1**
18 Nov	506	17	14	7.0		8.1	17,000	13,000	0.30	14	K1	K1	K1	J3.6	5.8**
9 Dec	570	-	-	-		-	9,200	790	0.05	12	12	6	6	J2.0	3.5**
(1976)															
20 Jan	854	-1	3.25	7.6		13.2	9,200	5,400	0.38	14	1	1	K1	J2.5**	J4
2 Feb	1,690	-0.6	3.0	7.2		14.0	1,300	1,300						-	-
24 Feb	774	10.0	5.0	7.45		12.9	400	140	0.17	9	2	2	K1	J1.8	J4**
29 Mar	295	15.0	9.5	7.2		10.6	3,500	1,700							
28 Apr	297						7,900	1,700							
27 May	217	20.	15	6.35			16,000	790							
7 Jun	no record	27.0	18	6.4			3,300	330							

*Average daily flow at Cranston Gage, Pawtuxet River (PROVISIONAL)
**Average of two values
K = less than J = estimated



BASIN SUB-DIVISIONS

AREA	DESCRIPTION	DRAINAGE AREA SQUARE MILES
A	Scituate Reservoir	92.8
B	Flat River Reservoir	56.7
L1	Local to USGS Gage Cranston	50.5
L2	Local From Cranston Gage to Mouth	30.4

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

WATER RESOURCES DEVELOPMENT PROJECT

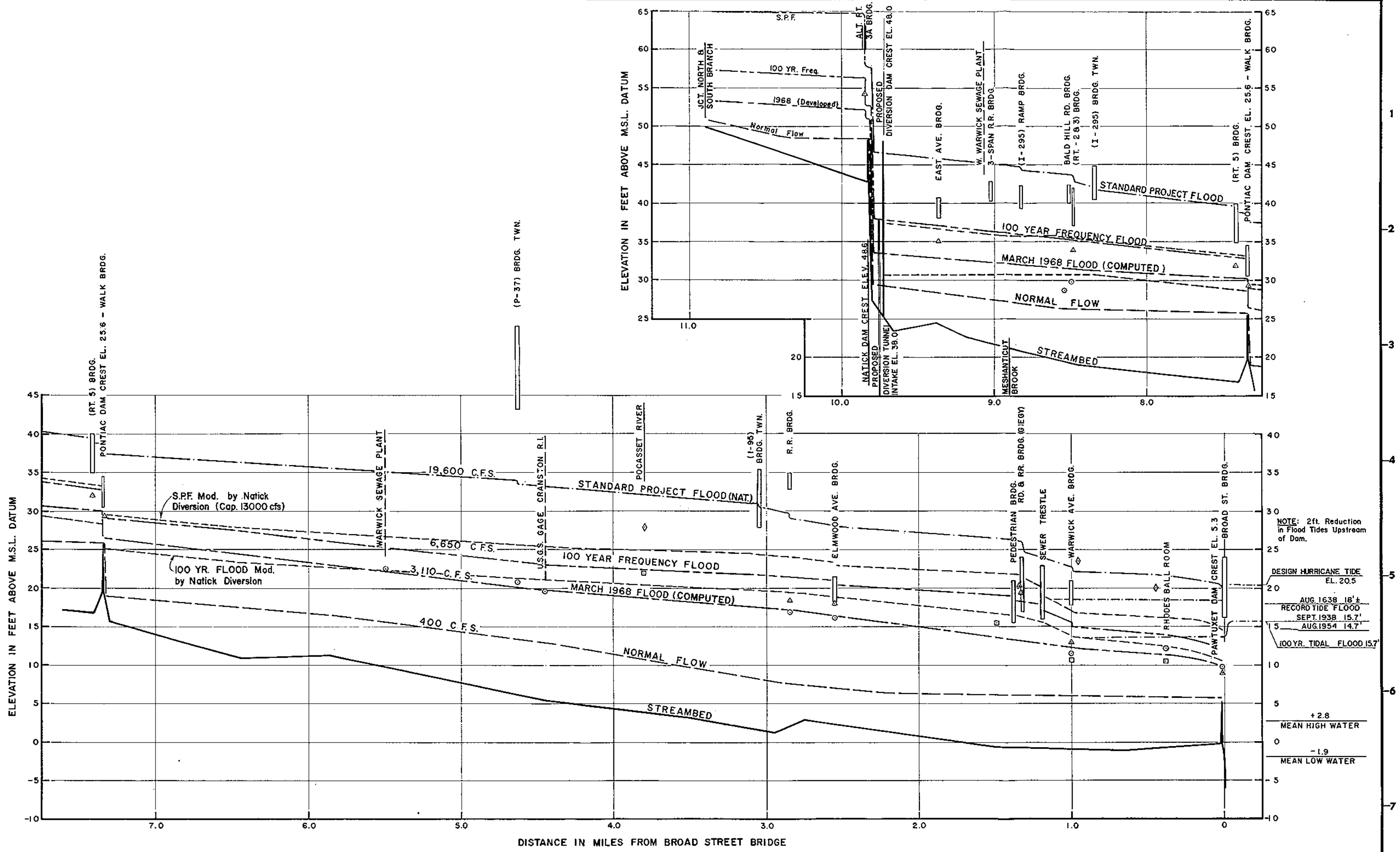
PAWTUXET RIVER BASIN

WATERSHED MAP

PAWTUXET RIVER RHODE ISLAND

PLATE 1

CORPS OF ENGINEERS U. S ARMY



PAWTUXET RIVER PROFILE

LEGEND:

- △ INDICATES H.W.M. JULY 1938
- ⊙ INDICATES H.W.M. MARCH 1968
- ⊡ INDICATES H.W.M. MARCH 1936
- ◇ INDICATES H.W.M. FEB. 1886

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

WATER RESOURCES DEVELOPMENT PROJECT
PAWTUXET RIVER BASIN
MAIN STEM
FLOOD PROFILES

PAWTUXET RIVER RHODE ISLAND

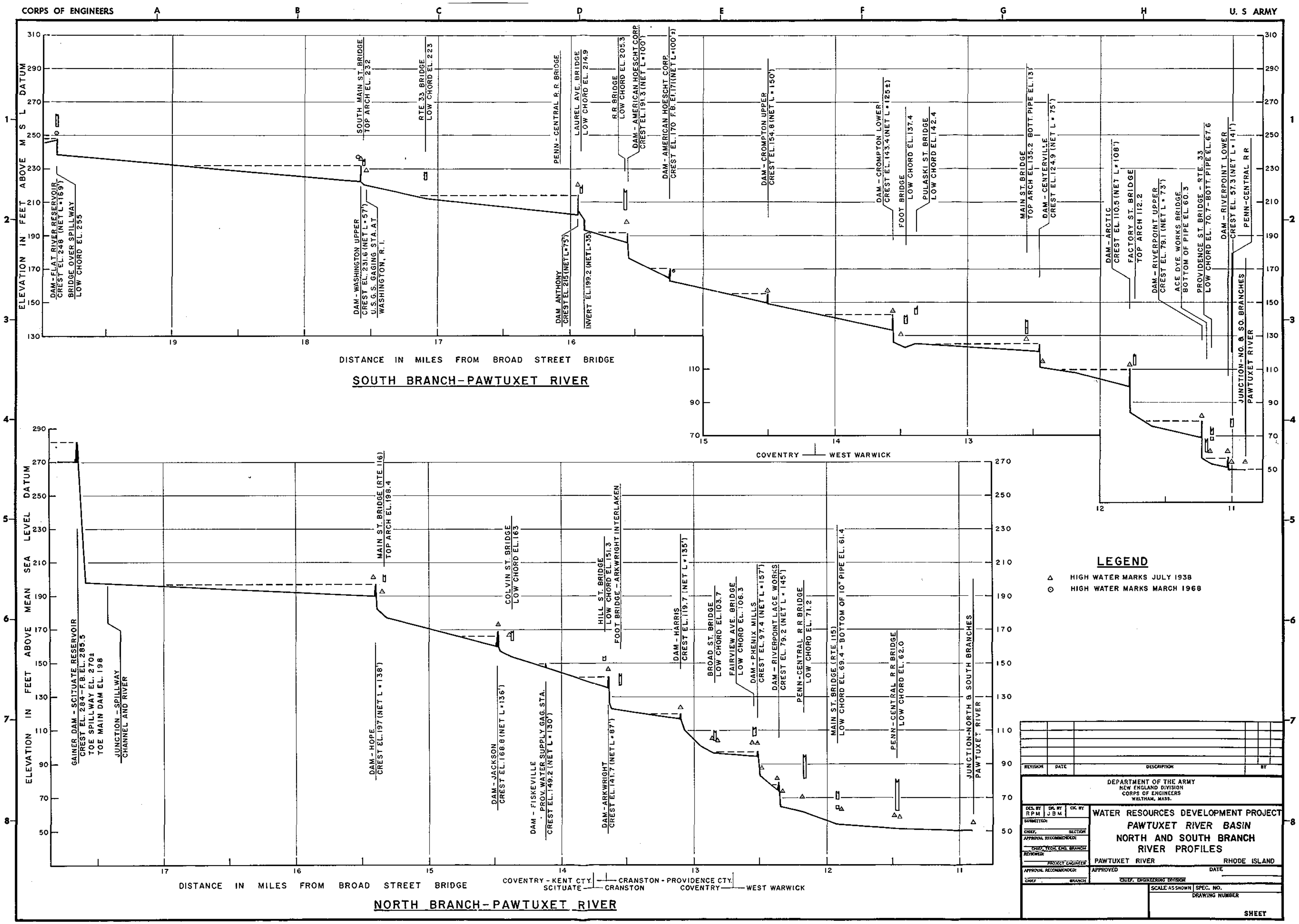

CORPS OF ENGINEERS
U. S. ARMY
ELEVATION IN FEET ABOVE M S L DATUM
DAM - FLAT RIVER RESERVOIR CREST EL. 248 (NET L = 169')
BRIDGE OVER SPILLWAY LOW CHORD EL. 255
SOUTH MAIN ST. BRIDGE TOP ARCH EL. 232
DAM - WASHINGTON UPPER CREST EL. 231.6 (NET L = 57')
U.S.G.S. GAGING STA. AT WASHINGTON, R. I.
RTE. 33 BRIDGE LOW CHORD EL. 223
PENN - CENTRAL R. R. BRIDGE
DAM ANTHONY CREST EL. 215 (NET L = 75')
LAUREL AVE. BRIDGE LOW CHORD EL. 214.9
INVERT EL. 199.2 (NET L = 35')
R.R. BRIDGE LOW CHORD EL. 205.3
DAM - AMERICAN HOESCHT CORP. CREST EL. 191.3 (NET L = 100')
DAM - AMERICAN HOESCHT CORP. CREST EL. 170 F.B. EL. 171 (NET L = 100')
DAM - CROMPTON UPPER CREST EL. 154.8 (NET L = 150')
DAM - CROMPTON LOWER CREST EL. 143.4 (NET L = 125±)
FOOT BRIDGE LOW CHORD EL. 137.4
PULASKI ST. BRIDGE LOW CHORD EL. 142.4
MAIN ST. BRIDGE TOP ARCH EL. 135.2 BOTT. PIPE EL. 131
DAM - CENTERVILLE CREST EL. 124.9 (NET L = 75')
DAM - ARCTIC CREST EL. 110.5 (NET L = 108')
FACTORY ST. BRIDGE TOP ARCH 112.2
DAM - RIVERPOINT UPPER CREST EL. 79.1 (NET L = 73')
ACE DYE WORKS BRIDGE BOTTOM OF PIPE EL. 60.3
PROVIDENCE ST. BRIDGE - RTE. 33 LOW CHORD EL. 70.7 - BOTT. PIPE EL. 67.6
DAM - RIVERPOINT LOWER CREST EL. 57.3 (NET L = 141')
PENN - CENTRAL R R
JUNCTION - NO. & SO. BRANCHES PAWTUXET RIVER
DISTANCE IN MILES FROM BROAD STREET BRIDGE
SOUTH BRANCH - PAWTUXET RIVER
COVENTRY — WEST WARWICK
ELEVATION IN FEET ABOVE MEAN SEA LEVEL DATUM
GAINER DAM - SCITUATE RESERVOIR CREST EL. 284 - F.B. EL. 285.5 TOE SPILLWAY EL. 270± TOE MAIN DAM EL. 198
JUNCTION - SPILLWAY CHANNEL AND RIVER
MAIN ST. BRIDGE (RTE 116) TOP ARCH EL. 198.4
DAM - HOPE CREST EL. 197 (NET L = 138')
COLVIN ST. BRIDGE LOW CHORD EL. 163
DAM - JACKSON CREST EL. 168.8 (NET L = 136')
DAM - FISKEVILLE - PROV. WATER SUPPLY GAG. STA. CREST EL. 149.2 (NET L = 130')
HILL ST. BRIDGE LOW CHORD EL. 151.3
FOOT BRIDGE - ARKWRIGHT INTERLAKEN
DAM - ARKWRIGHT CREST EL. 141.7 (NET L = 87')
DAM - HARRIS CREST EL. 119.7 (NET L = 135')
BROAD ST. BRIDGE LOW CHORD EL. 103.7
FAIRVIEW AVE. BRIDGE LOW CHORD EL. 106.3
DAM - PHENIX MILLS CREST EL. 97.4 (NET L = 157')
DAM - RIVERPOINT LACE WORKS CREST EL. 79.2 (NET L = 145')
PENN - CENTRAL R.R. BRIDGE LOW CHORD EL. 71.2
MAIN ST. BRIDGE (RTE 115) LOW CHORD EL. 69.4 - BOTTOM OF 10" PIPE EL. 61.4
PENN - CENTRAL R.R. BRIDGE LOW CHORD EL. 62.0
JUNCTION - NORTH & SOUTH BRANCHES PAWTUXET RIVER
DISTANCE IN MILES FROM BROAD STREET BRIDGE
COVENTRY - KENT CTY. — CRANSTON - PROVIDENCE CTY.
SCITUATE — CRANSTON
COVENTRY — WEST WARWICK
NORTH BRANCH - PAWTUXET RIVER
LEGEND
HIGH WATER MARKS JULY 1938
HIGH WATER MARKS MARCH 1968
REVISION DATE DESCRIPTION BY
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.
WATER RESOURCES DEVELOPMENT PROJECT
PAWTUXET RIVER BASIN
NORTH AND SOUTH BRANCH
RIVER PROFILES
PAWTUXET RIVER RHODE ISLAND
SCALE: AS SHOWN
SPEC. NO.
DRAWING NUMBER
SHEET

PLATE 3

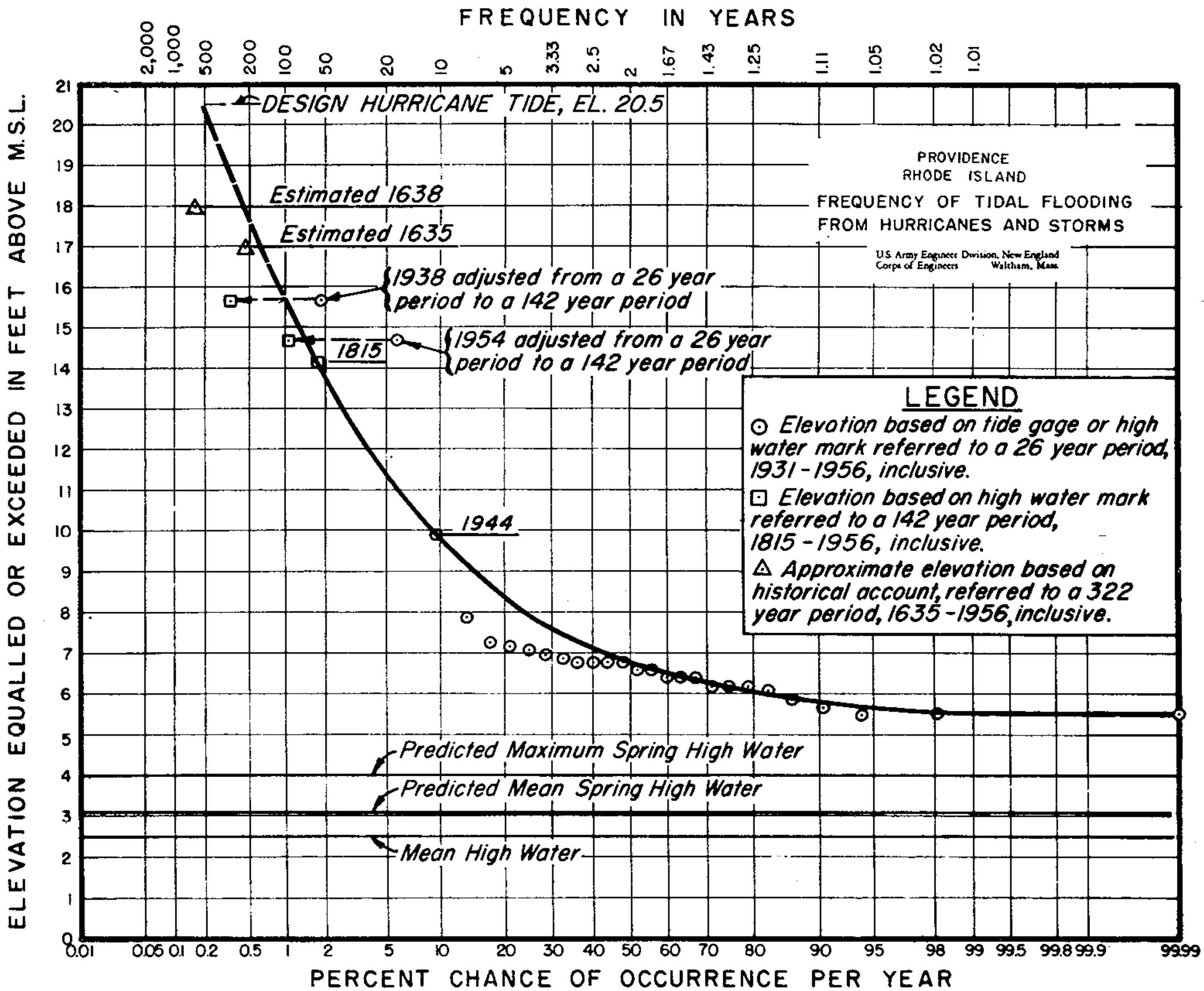
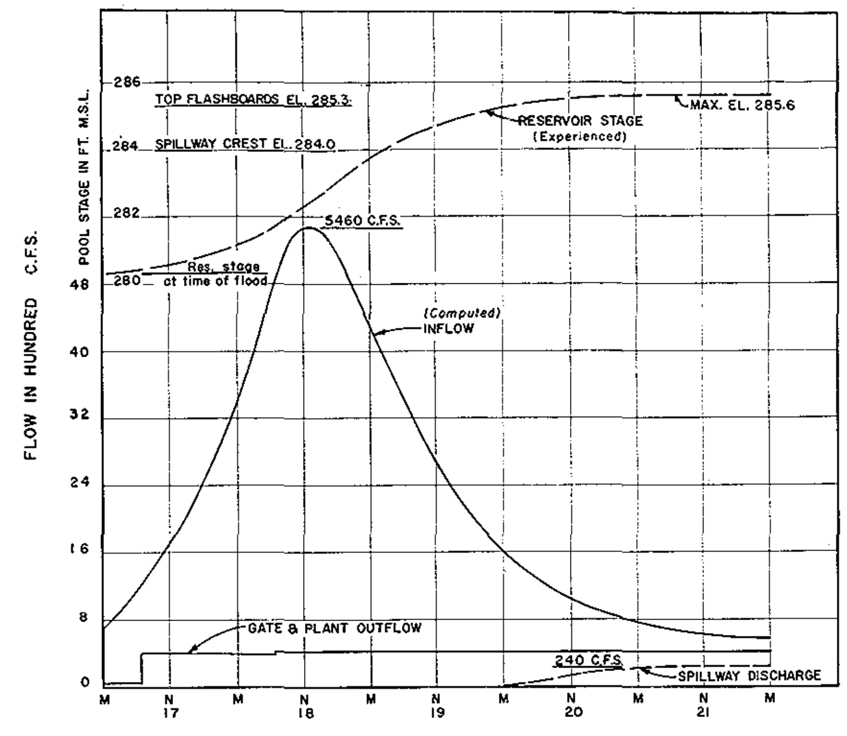
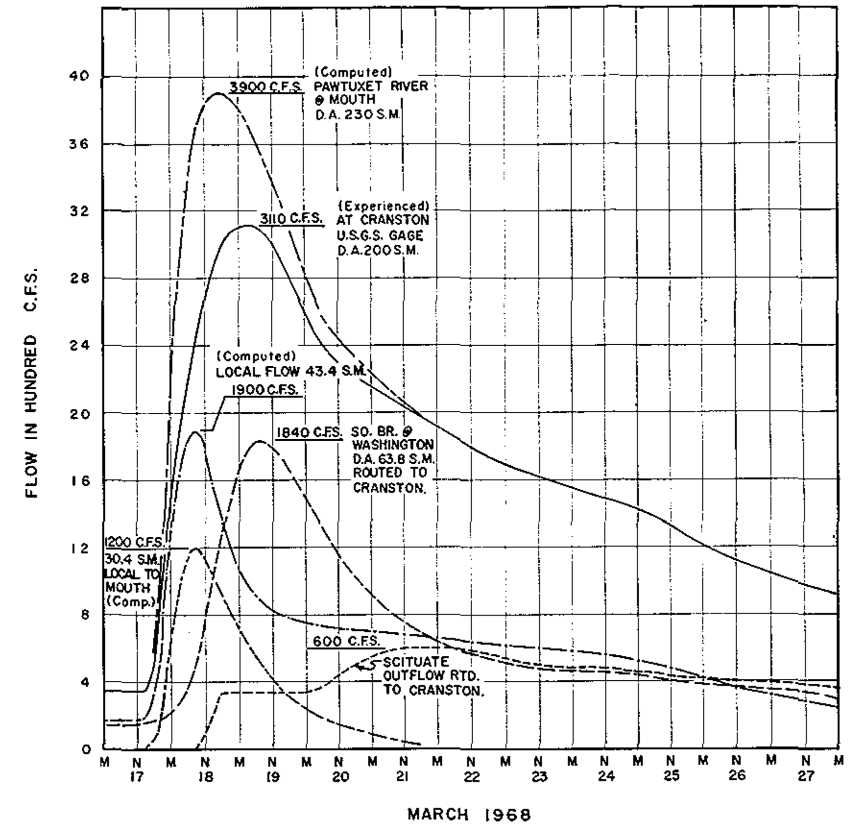

FREQUENCY IN YEARS
2,000 1,000 500 200 100 50 20 10 5 3.33 2.5 2 1.67 1.43 1.25 1.11 1.05 1.02 1.01
DESIGN HURRICANE TIDE, EL. 20.5
Estimated 1638
Estimated 1635
1938 adjusted from a 26 year period to a 142 year period
1815
1954 adjusted from a 26 year period to a 142 year period
1944
PROVIDENCE
RHODE ISLAND
FREQUENCY OF TIDAL FLOODING
FROM HURRICANES AND STORMS
U.S. Army Engineer Division, New England
Corps of Engineers Waltham, Mass.
LEGEND
⊙ Elevation based on tide gage or high water mark referred to a 26 year period, 1931-1956, inclusive.
⊡ Elevation based on high water mark referred to a 142 year period, 1815-1956, inclusive.
△ Approximate elevation based on historical account, referred to a 322 year period, 1635-1956, inclusive.
Predicted Maximum Spring High Water
Predicted Mean Spring High Water
Mean High Water
ELEVATION EQUALLED OR EXCEEDED IN FEET ABOVE M.S.L.
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
0.01 0.05 0.1 0.2 0.5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.5 99.8 99.9 99.99
PERCENT CHANCE OF OCCURRENCE PER YEAR

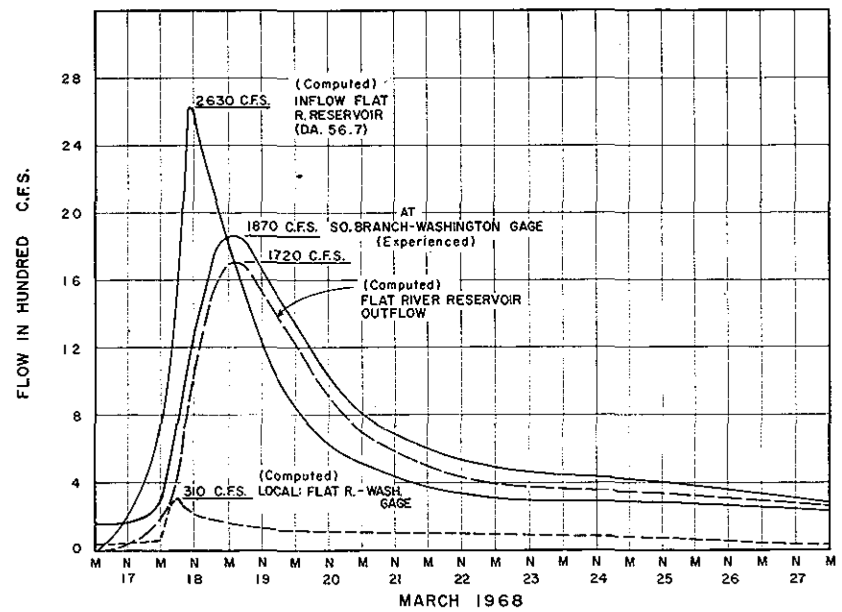
PLATE 4



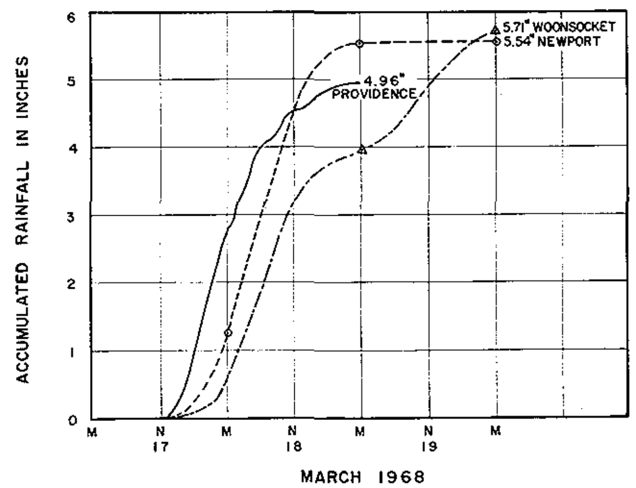
SCITUATE RESERVOIR
(DA. 92.8 Sq.Mi.)



FLOOD COMPONENTS AT CRANSTON U.S.G.S. GAGE AND AT MOUTH OF PAWTUXET RIVER



SOUTH BRANCH PAWTUXET RIVER
AT
WASHINGTON R.I. (DA. 63.8 Sq. Mi.)



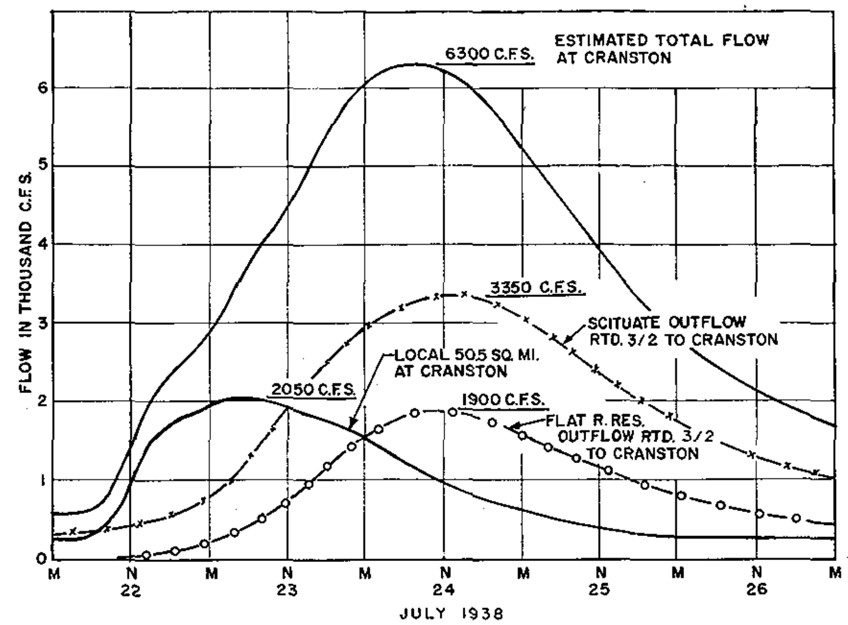
MASS RAINFALL CURVES
(⊙, △ INDICATE OBSERVED RAINFALL VALUE)

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

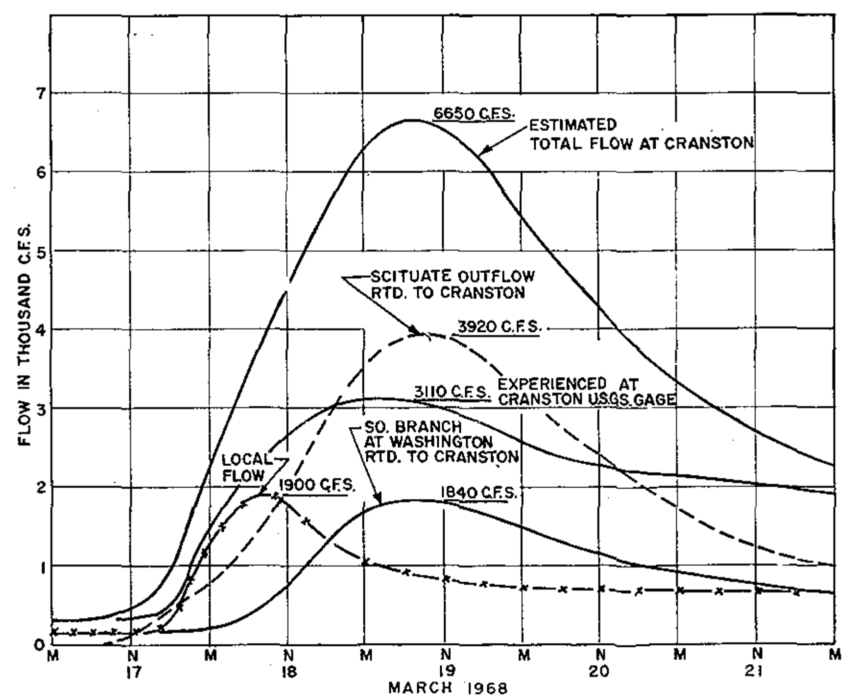
WATER RESOURCES DEVELOPMENT PROJECT

PAWTUXET RIVER BASIN
MARCH 1968 FLOOD
ANALYSIS

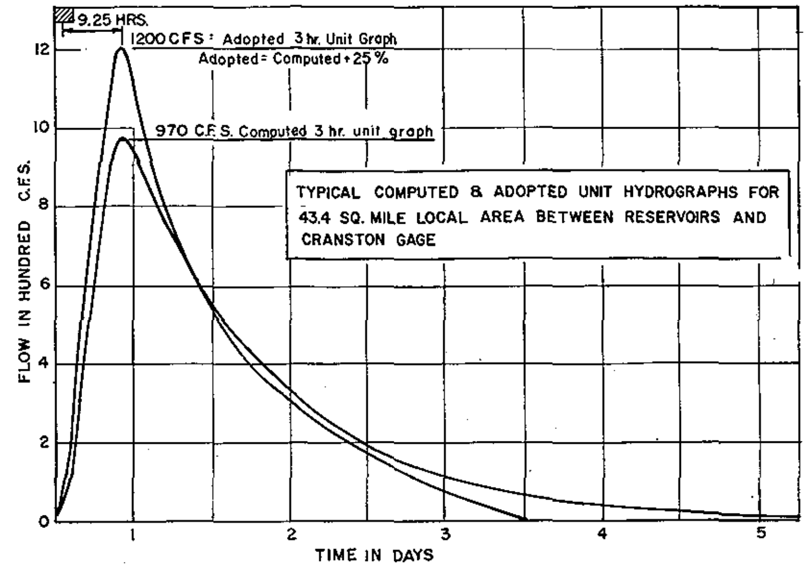
PAWTUXET RIVER RHODE ISLAND

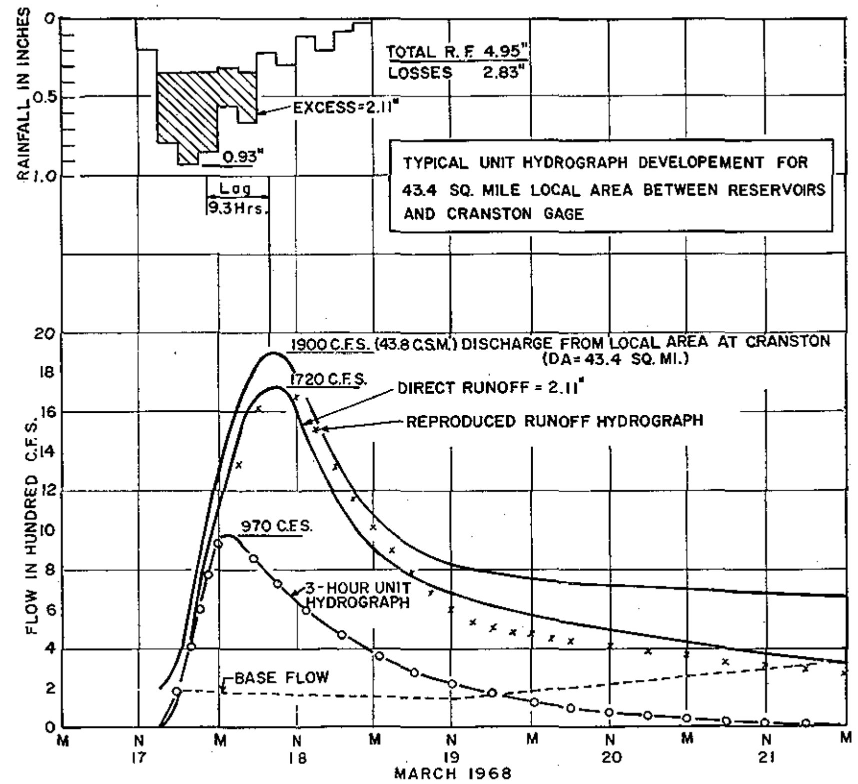


RECONSTRUCTED JULY 1938 FLOOD
AT CRANSTON R.I.



HYPOTHETICAL MARCH 1968 FLOOD
IF SCITUATE RESERVOIR WAS FULL AT START OF FLOOD





UNIT HYDROGRAPH ANALYSIS

WATER RESOURCES DEVELOPMENT PROJECT

PAWTUXET RIVER BASIN
FLOOD COMPONENTS
AND
UNIT HYDROGRAPH
ANALYSIS

PAWTUXET RIVER | RHODE ISLAND

PLATE 6

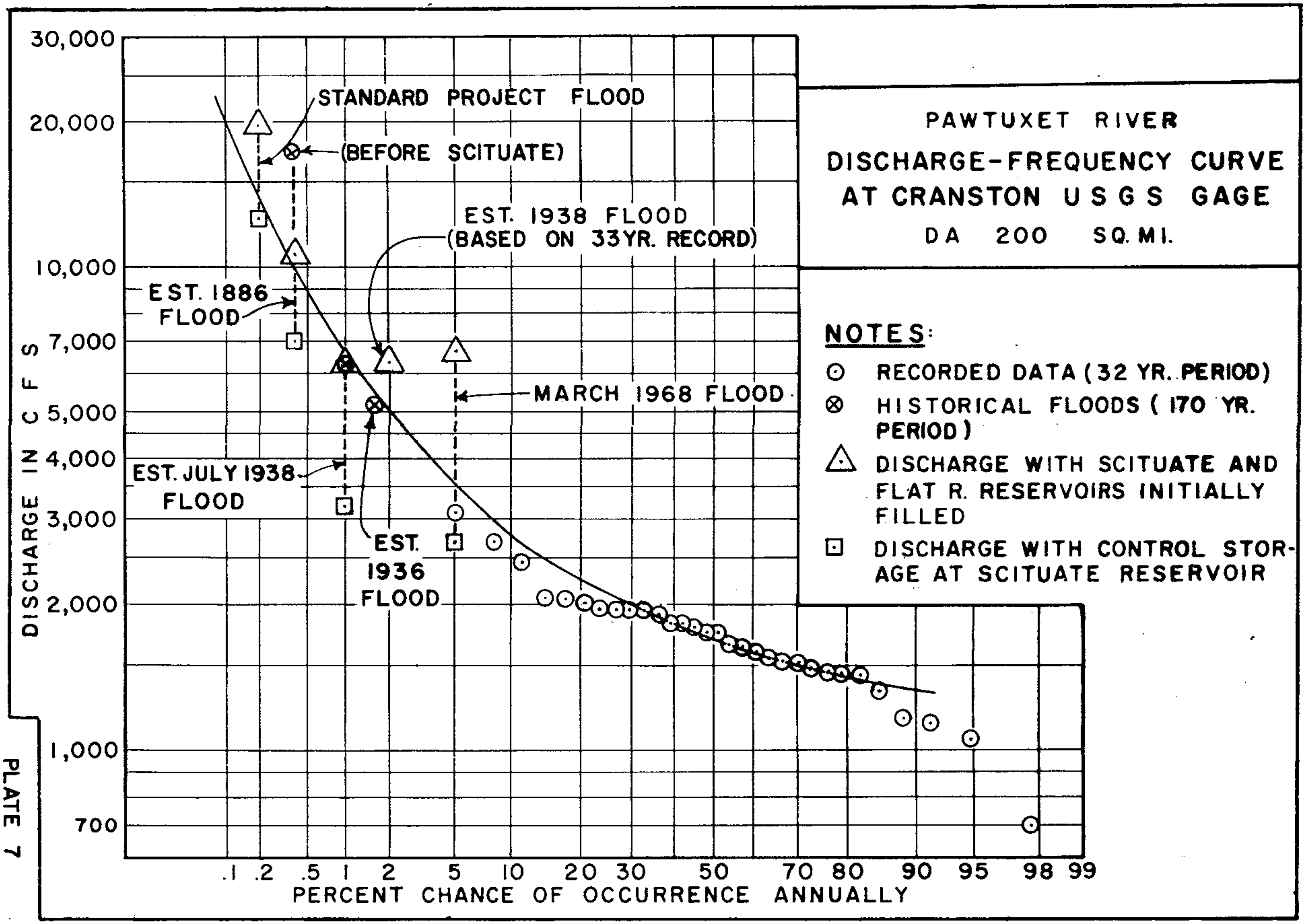
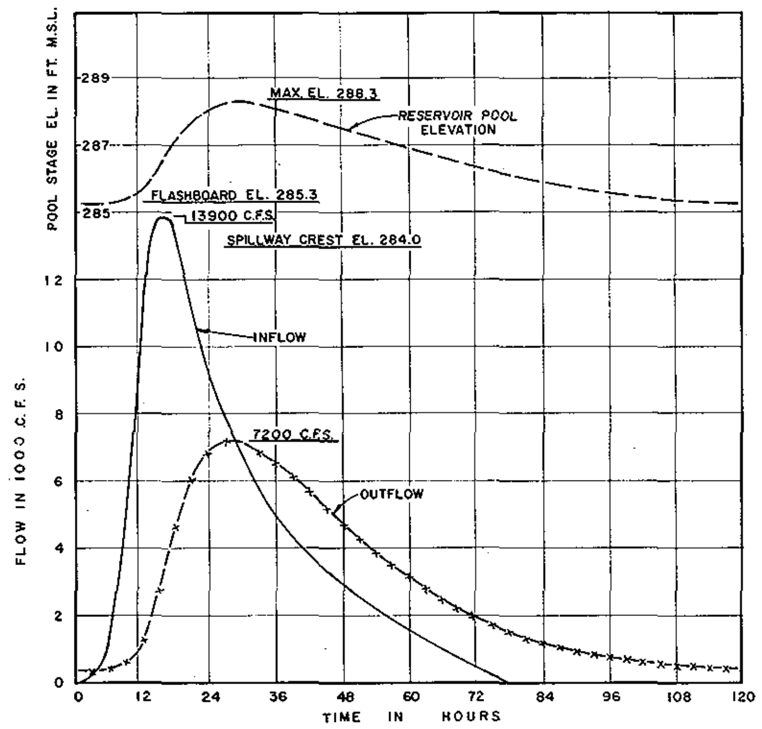
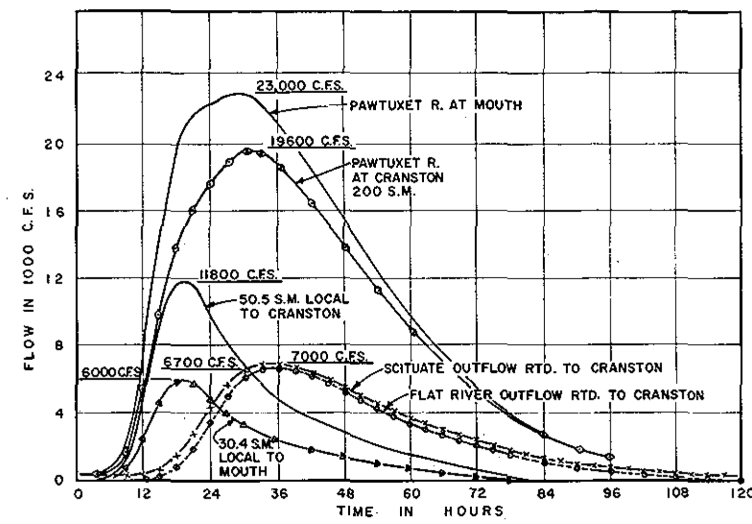

PAWTUXET RIVER
DISCHARGE-FREQUENCY CURVE AT CRANSTON USGS GAGE
DA 200 SQ. MI.
NOTES:
RECORDED DATA (32 YR. PERIOD)
HISTORICAL FLOODS (170 YR. PERIOD)
DISCHARGE WITH SCITUATE AND FLAT R. RESERVOIRS INITIALLY FILLED
DISCHARGE WITH CONTROL STORAGE AT SCITUATE RESERVOIR
STANDARD PROJECT FLOOD
(BEFORE SCITUATE)
EST. 1938 FLOOD (BASED ON 33 YR. RECORD)
EST. 1886 FLOOD
MARCH 1968 FLOOD
EST. JULY 1938 FLOOD
EST. 1936 FLOOD
DISCHARGE IN C F S
PERCENT CHANCE OF OCCURRENCE ANNUALLY
30,000
20,000
10,000
7,000
5,000
4,000
3,000
2,000
1,000
700
.1 .2 .5 1 2 5 10 20 30 50 70 80 90 95 98 99

PLATE 7

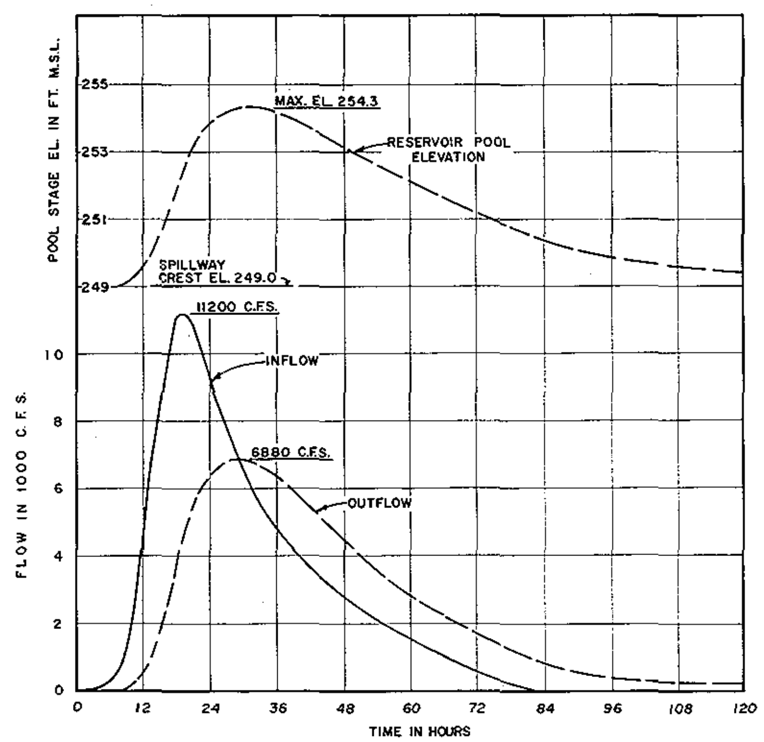
CORPS OF ENGINEERS — U. S ARMY



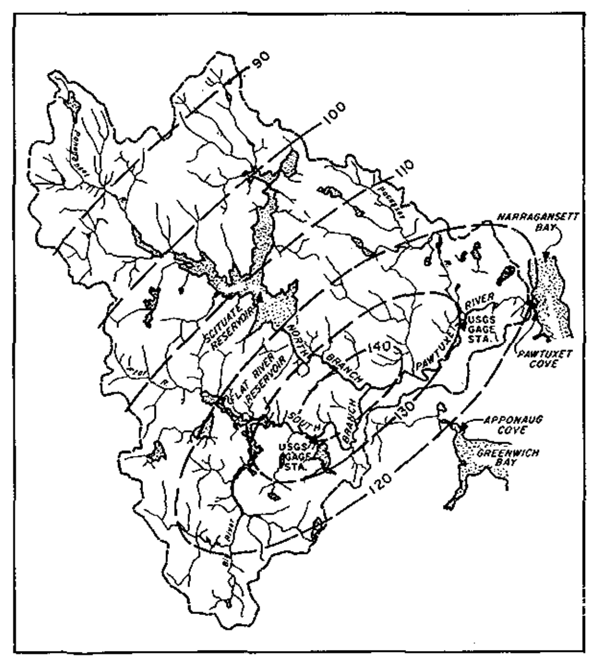
SCITUATE RESERVOIR



PAWTUXET RIVER BASIN



FLAT RIVER RESERVOIR

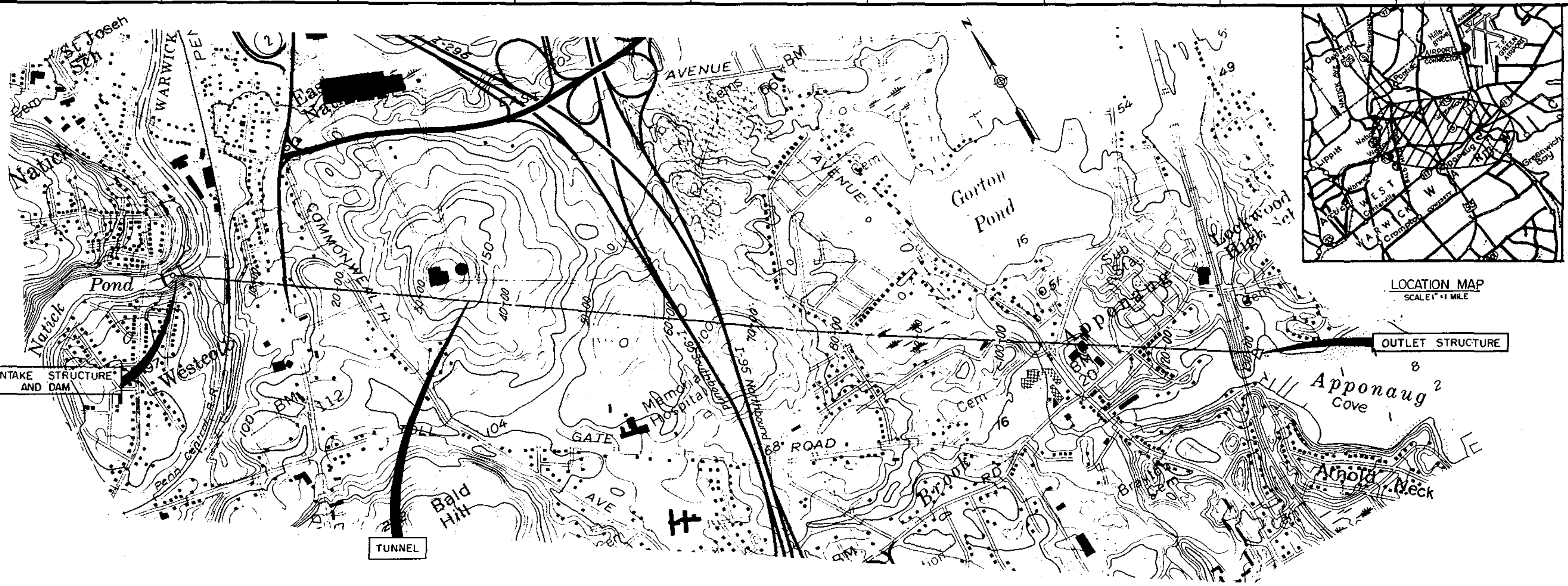


STANDARD PROJECT STORM
PATTERN IN PERCENT OF 96 HR-200 SQ. MILE INDEX RAINFALL

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

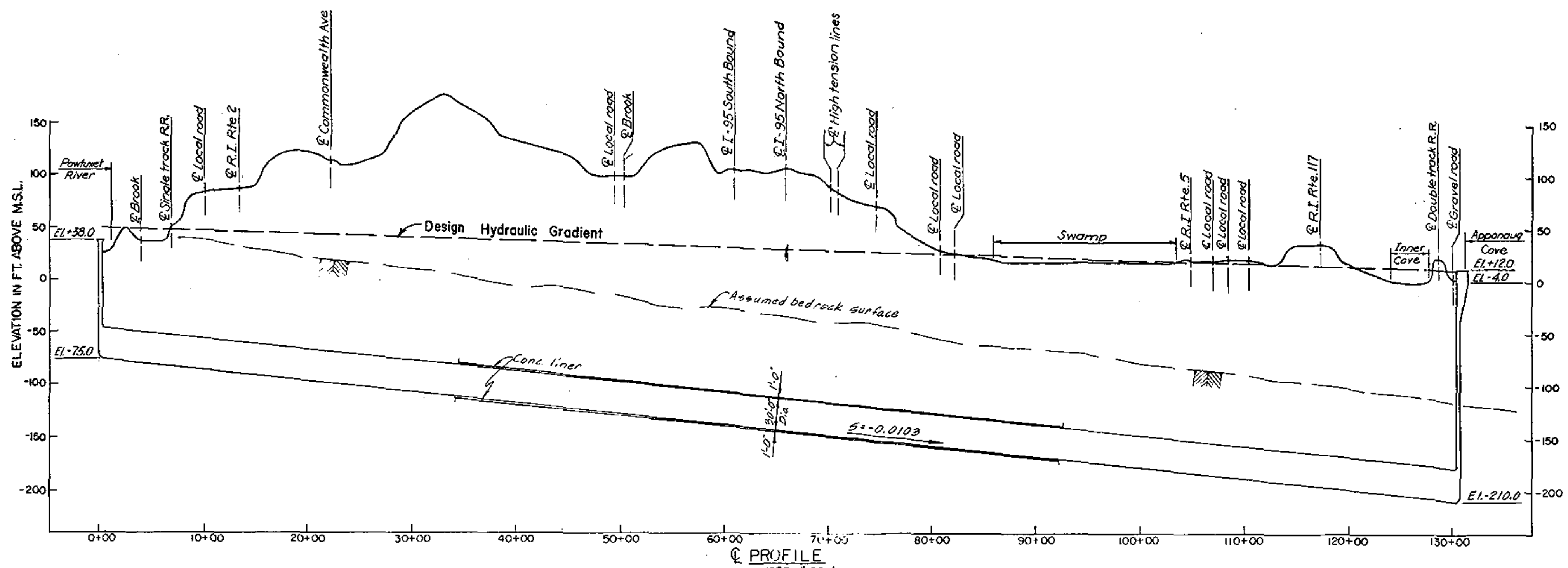
WATER RESOURCES DEVELOPMENT PROJECT
PAWTUXET RIVER BASIN
STANDARD PROJECT FLOOD
PAWTUXET RIVER — RHODE ISLAND

PLATE 8



PLAN
SCALE 1" = 500'

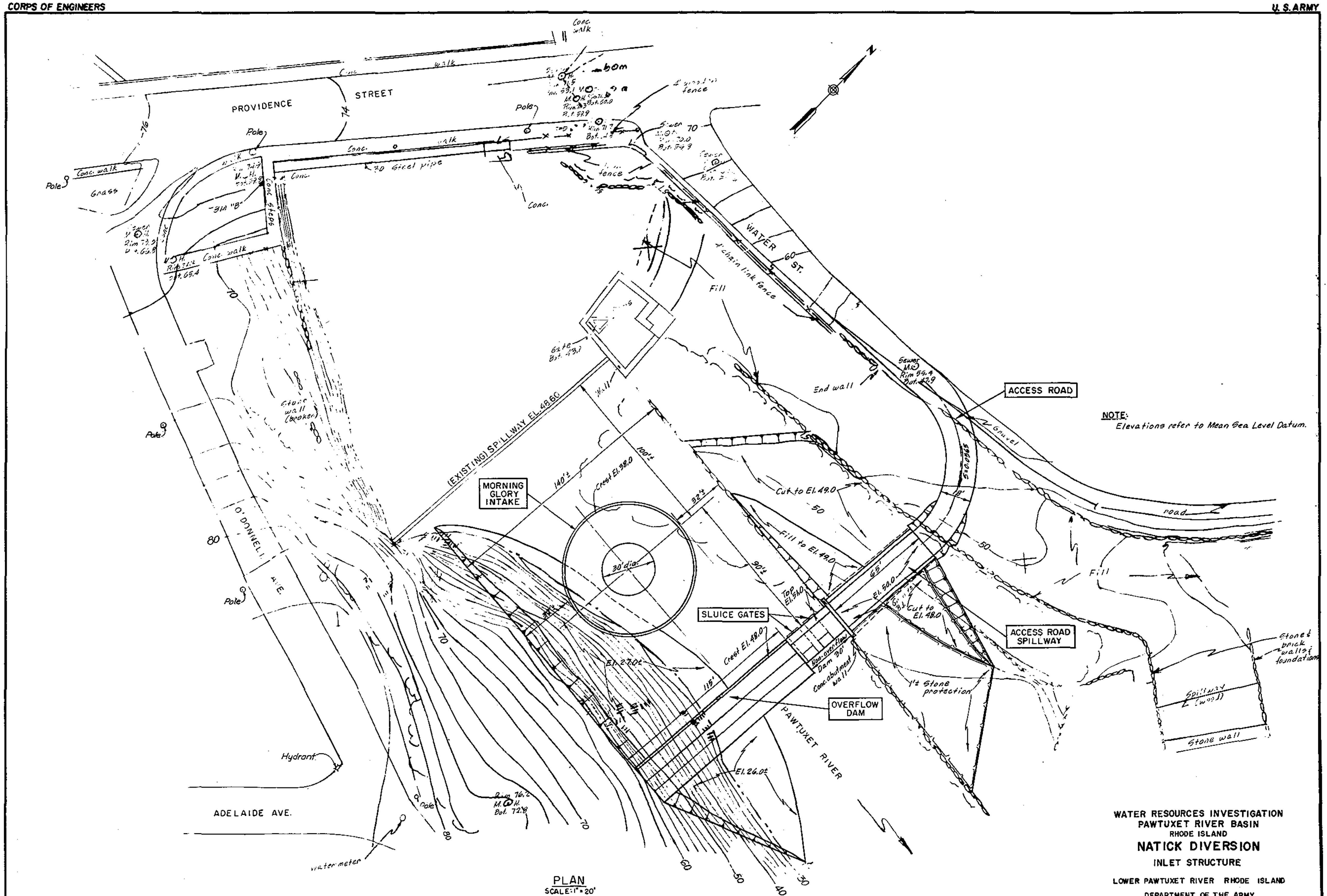
NOTE
Plan from U.S.G.S.
(photo revised) 1970 Quadrangle map



℄ PROFILE
SCALE: HORZ. 1" = 500' VERT. 1" = 50'

GRAPHIC SCALES
1" = 500' 500' 0 500' 1000'
1" = 50' 50' 0 50' 100'

WATER RESOURCES INVESTIGATION
PAWTUXET RIVER BASIN
RHODE ISLAND
NATICK DIVERSION
GENERAL PLAN
AND PROFILE
LOWER PAWTUXET RIVER RHODE ISLAND
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.



WATER RESOURCES INVESTIGATION
PAWTUXET RIVER BASIN
RHODE ISLAND

NATICK DIVERSION

INLET STRUCTURE

LOWER PAWTUXET RIVER RHODE ISLAND

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

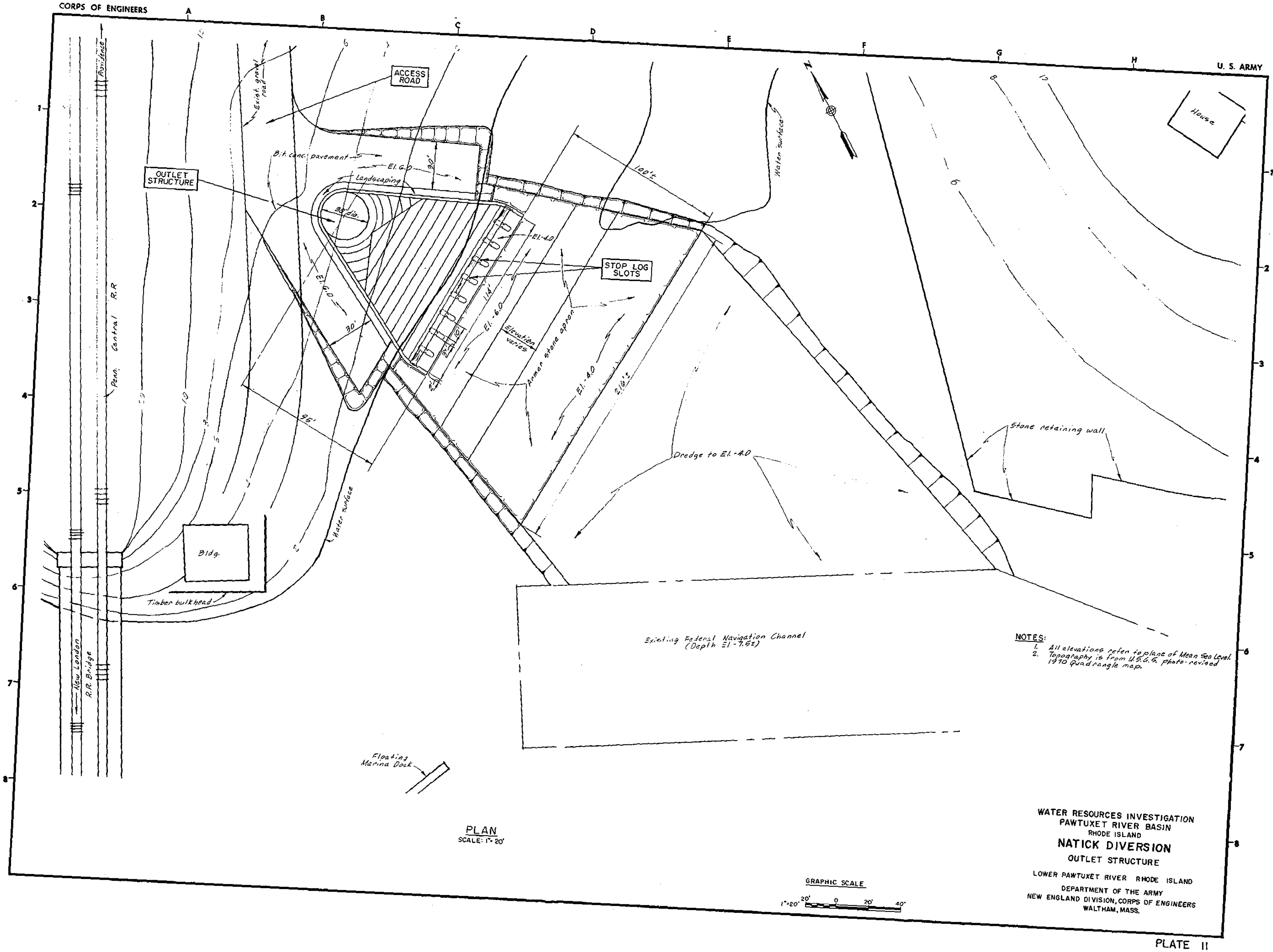
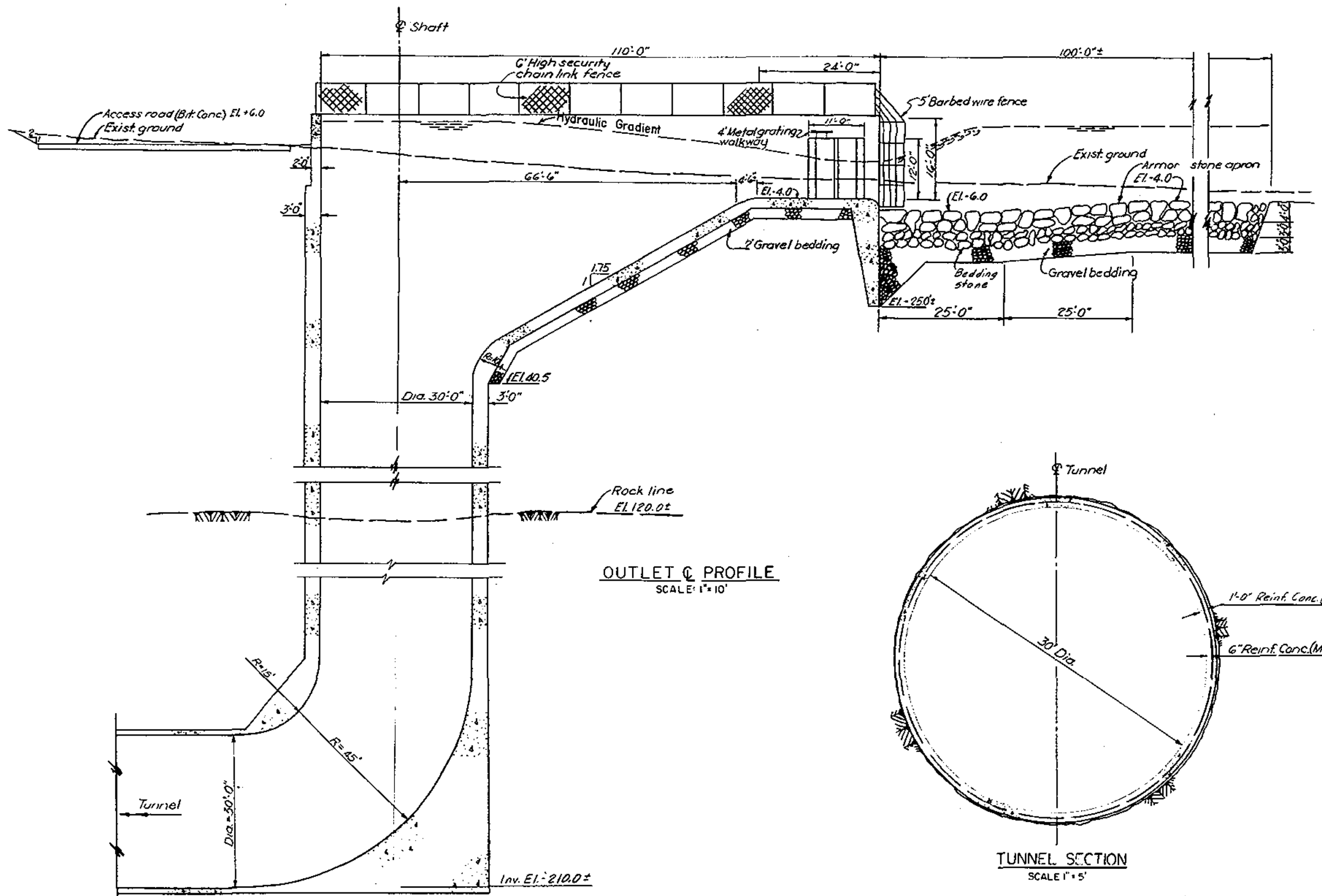
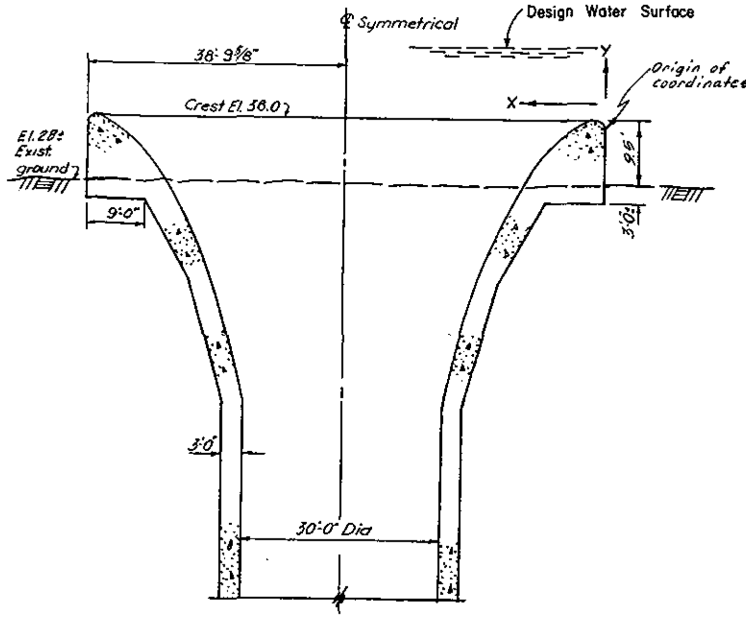

CORPS OF ENGINEERS
U. S. ARMY
ACCESS ROAD
OUTLET STRUCTURE
STOP LOG SLOTS
Exist. gravel road
Bit. conc. pavement
Landscaping
El. 6.0
El. -4.0
El. -6.0
30'
95'
100'±
114'
216'±
Elevation varies
Armor stone apron
Water surface
Dredge to El. -4.0
Stone retaining wall
House
Bldg.
Timber bulkhead
Penn. Central R.R.
Providence
New London
R.R. Bridge
Existing Federal Navigation Channel
(Depth El -7.5±)
Floating Marina Dock
NOTES:
1. All elevations refer to plane of Mean Sea Level.
2. Topography is from U.S.G.S. photo-revised 1970 Quadrangle map.
PLAN
SCALE: 1"= 20'
GRAPHIC SCALE
1"=20'
WATER RESOURCES INVESTIGATION
PAWTUXET RIVER BASIN
RHODE ISLAND
NATICK DIVERSION
OUTLET STRUCTURE
LOWER PAWTUXET RIVER RHODE ISLAND
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

PLATE II



OUTLET ℄ PROFILE
SCALE: 1"=10'

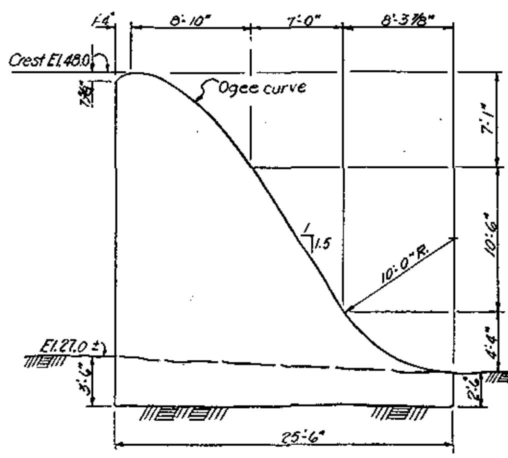


MORNING GLORY SECTION
SCALE 1"=10'

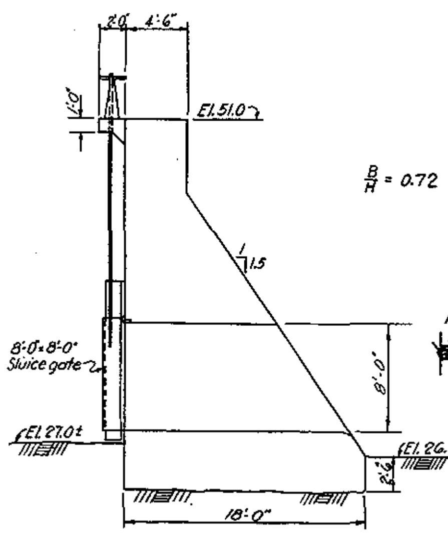
TUNNEL SECTION
SCALE 1"=5'

X	Y	(FT. M.S.L.)
0	00	(37.38)
0.7	.52	(37.90)
1.4	.62	(38.00)
2.1	.55	(37.93)
2.8	.35	(37.73)
3.5	.06	(37.44)
3.6	0.0	(37.38)
4.8	-0.7	(36.68)
5.8	-1.4	(35.98)
6.7	-2.1	(35.28)
7.4	-2.8	(34.58)
8.1	-3.5	(33.88)
10.8	-7.0	(30.38)
14.9	-14.0	(23.38)
17.9	-21.0	(16.38)
20.4	-28.0	(9.38)
22.2	-35.0	(2.38)
23.8	-42.0	(-4.62)

MORNING GLORY COORDINATE TABLE

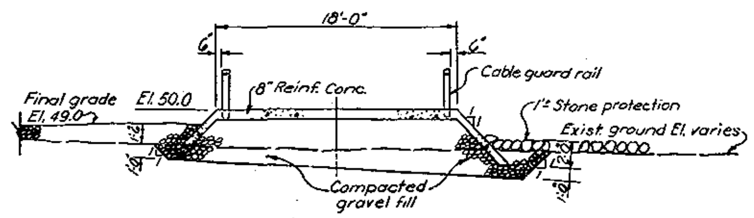


OVERFLOW DAM SECTION
SCALE: 1"=5'



NON-OVERFLOW DAM SECTION
SCALE: 1"=5'

$\frac{B}{H} = 0.72$



ACCESS ROAD/SPILLWAY SECTION
SCALE 1"=5'

GRAPHIC SCALES
1"=10' 10' 0 10' 20'
1"=5' 5' 0 5' 10'

WATER RESOURCES INVESTIGATION
PAWTUXET RIVER BASIN
RHODE ISLAND

NATICK DIVERSION

PROFILE AND SECTIONS

LOWER PAWTUXET RIVER RHODE ISLAND

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

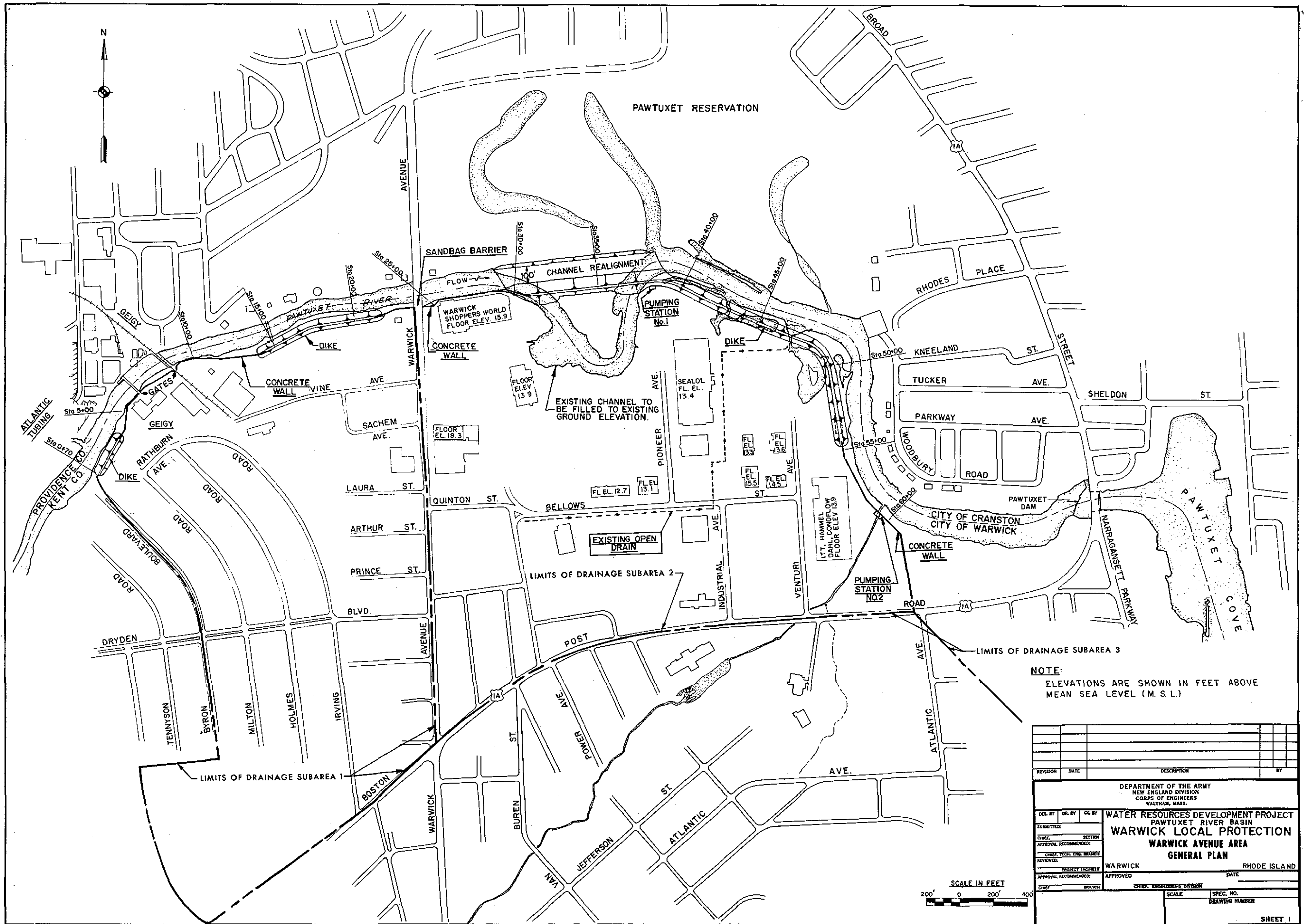
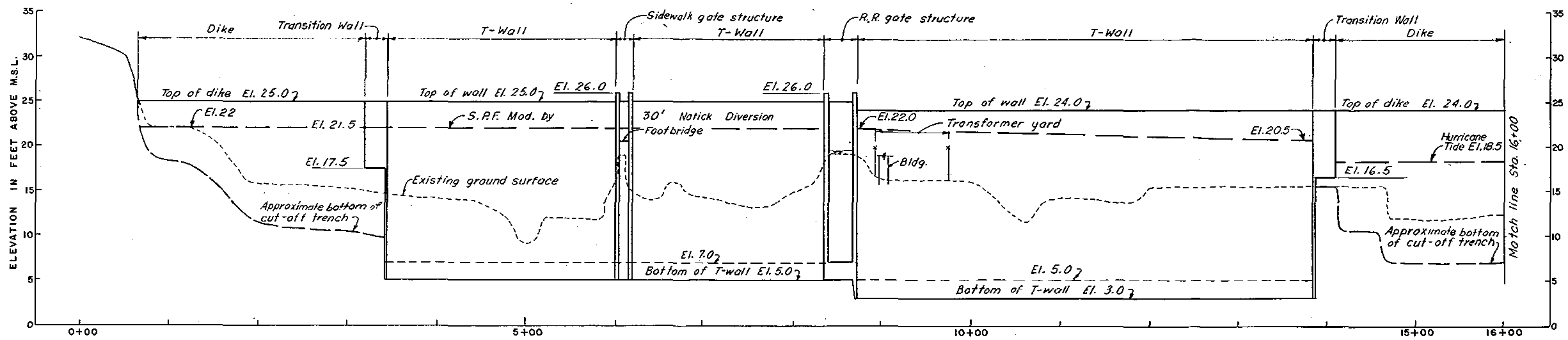
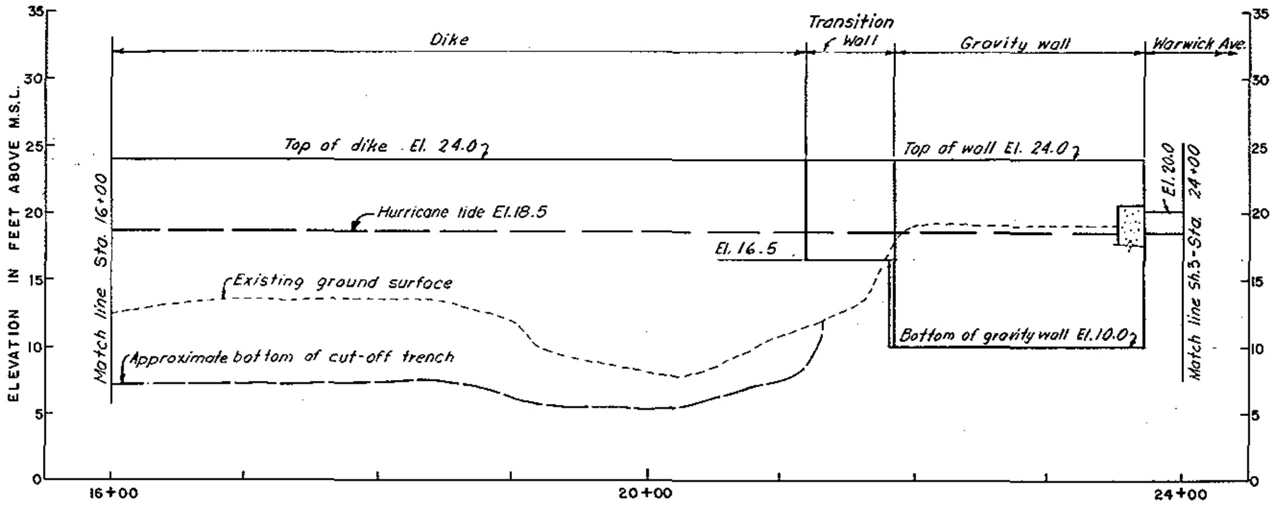

N
PAWTUXET RESERVATION
BROAD STREET
1A
RHODES PLACE
KNEELAND ST.
TUCKER AVE.
SHELDON ST.
PARKWAY AVE.
WOODBURY ROAD
PAWTUXET DAM
CITY OF CRANSTON
CITY OF WARWICK
NARRAGANSETT PARKWAY
PAWTUXET COVE
SANDBAG BARRIER
FLOW
100'
CHANNEL REALIGNMENT
PAWTUXET RIVER
WARWICK SHOPPERS WORLD FLOOR ELEV. 15.9
CONCRETE WALL
DIKE
PUMPING STATION No.1
PUMPING STATION No.2
Sta 0+70
Sta 5+00
Sta 10+00
Sta 15+00
Sta 20+00
Sta 25+00
Sta 30+00
Sta 35+00
Sta 40+00
Sta 45+00
Sta 50+00
Sta 55+00
Sta 60+00
ATLANTIC TUBING
PROVIDENCE CO.
KENT CO.
GATES
GEIGY
RATHBURN AVE.
VINE AVE.
SACHEM AVE.
FLOOR ELEV 13.9
FLOOR EL. 18.3
EXISTING CHANNEL TO BE FILLED TO EXISTING GROUND ELEVATION.
SEALOL FL EL. 13.4
FL EL 13.3
FL EL 13.6
FL EL 15.5
FL EL 14.5
FL EL 12.7
FL EL 13.1
ITT HAMMEL DAHL, CONOFLOW FLOOR ELEV 13.9
PIONEER AVE.
BELLOWS ST.
INDUSTRIAL AVE.
VENTURI AVE.
EXISTING OPEN DRAIN
LAURA ST.
QUINTON ST.
ARTHUR ST.
PRINCE ST.
BLVD.
LIMITS OF DRAINAGE SUBAREA 2
LIMITS OF DRAINAGE SUBAREA 3
LIMITS OF DRAINAGE SUBAREA 1
WARWICK AVENUE
BOULEVARD
ROAD
DRYDEN
TENNYSON
BYRON
MILTON
HOLMES
IRVING
POST ROAD
BOSTON
ST.
POWER AVE.
BUREN
VAN
JEFFERSON ST.
ATLANTIC AVE.
NOTE:
ELEVATIONS ARE SHOWN IN FEET ABOVE MEAN SEA LEVEL (M. S. L.)
SCALE IN FEET
200' 0 200' 400'
REVISION DATE DESCRIPTION BY
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.
DES. BY DR. BY CK. BY
SUBMITTED:
CHIEF, SECTION
APPROVAL RECOMMENDED:
CHIEF, TECH. ENG. BRANCH
REVIEWED:
PROJECT ENGINEER
APPROVAL RECOMMENDED:
CHIEF BRANCH
WATER RESOURCES DEVELOPMENT PROJECT
PAWTUXET RIVER BASIN
WARWICK LOCAL PROTECTION
WARWICK AVENUE AREA
GENERAL PLAN
WARWICK RHODE ISLAND
APPROVED DATE
CHIEF, ENGINEERING DIVISION
SCALE SPEC. NO.
DRAWING NUMBER
SHEET 1

PLATE 13



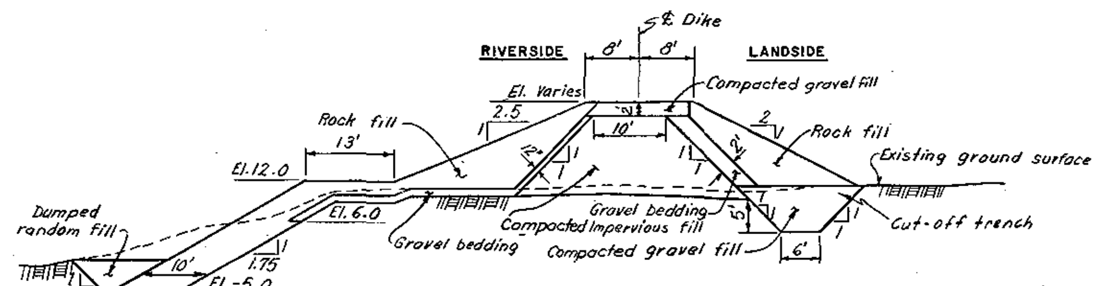
℄ PROFILE

SCALE: HOR 1" = 50' VERT 1" = 5'

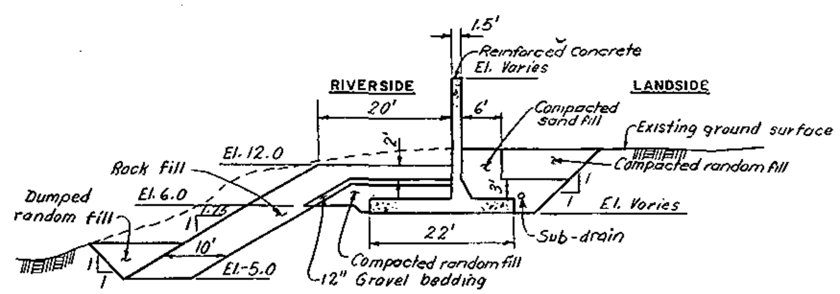


℄ PROFILE (CONT.)

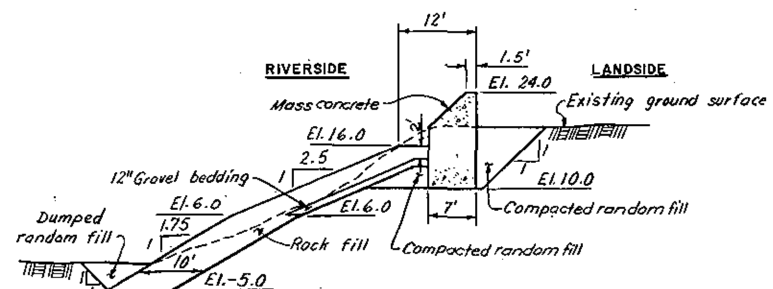
SCALE: HOR 1" = 50' VERT 1" = 5'



DIKE



T - WALL



GRAVITY WALL

TYPICAL SECTIONS

SCALE 1" = 10'

SCALE IN FEET

REVISION	DATE	DESCRIPTION	BY

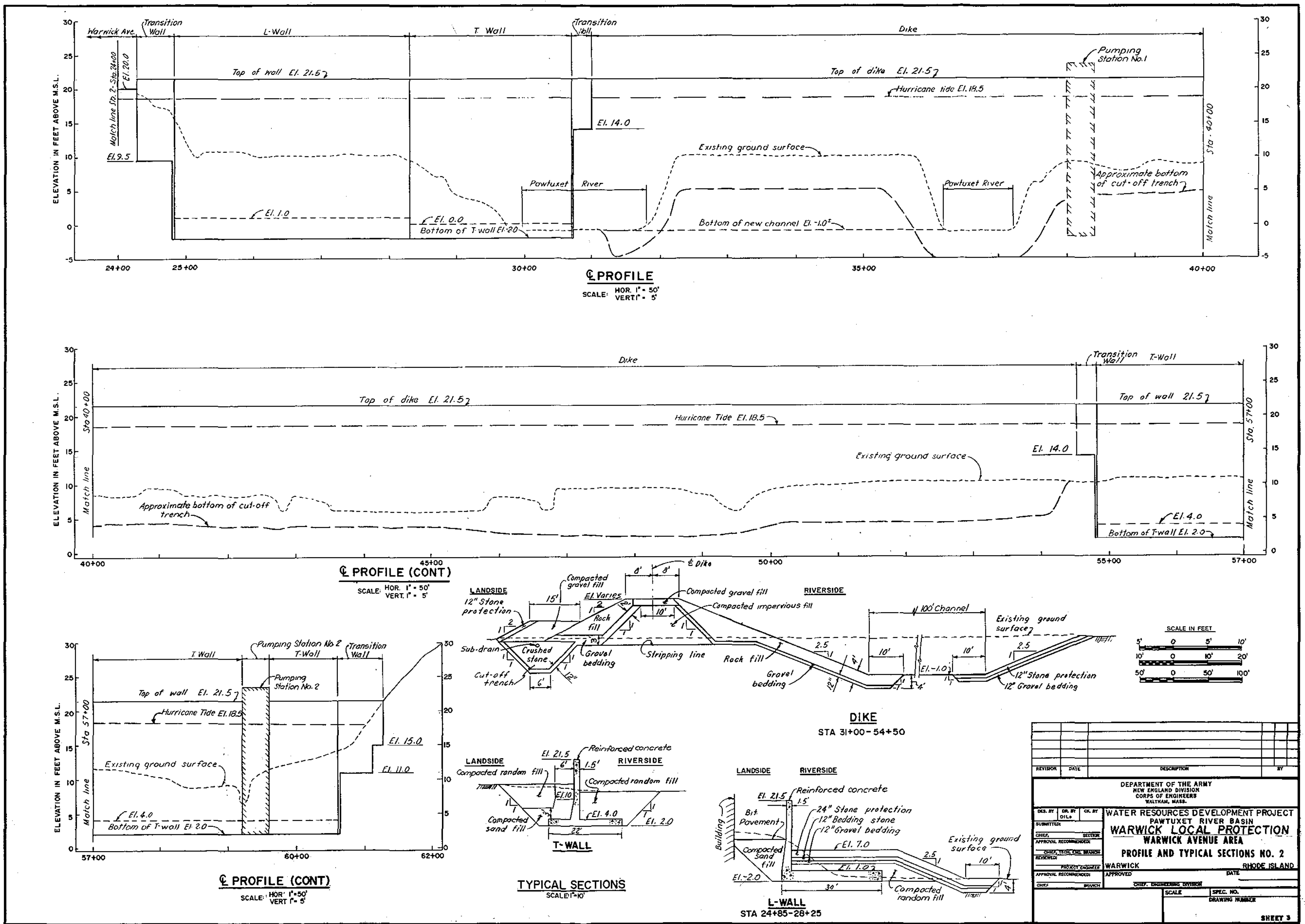
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

WATER RESOURCES DEVELOPMENT PROJECT
PAWTUXET RIVER BASIN
WARWICK LOCAL PROTECTION
WARWICK AVENUE AREA
PROFILE AND TYPICAL SECTIONS NO. 1

WARWICK RHODE ISLAND

SHEET 2

PLATE 14



℄ PROFILE
SCALE: HOR. 1" = 50' VERT. 1" = 5'
ELEVATION IN FEET ABOVE M.S.L.
Warwick Ave.
Transition Wall
L-Wall
T Wall
Dike
Match line Sta. 2-Sta. 24+00
El. 20.0
El. 9.5
Top of wall El. 21.5
Top of dike El. 21.5
Hurricane tide El. 18.5
El. 14.0
El. 1.0
El. 0.0
Bottom of T-wall El -2.0
Pawtuxet River
Existing ground surface
Bottom of new channel El. -1.0±
Pumping Station No. 1
Approximate bottom of cut-off trench
Sta. 40+00
Match line
24+00
25+00
30+00
35+00
40+00
℄ PROFILE (CONT)
SCALE: HOR. 1" = 50' VERT. 1" = 5'
Sta 40+00
Hurricane Tide El. 18.5
Approximate bottom of cut-off trench
Transition Wall
T-Wall
Top of wall 21.5
El. 14.0
El. 4.0
Bottom of T-wall El. 2.0
Sta. 57+00
45+00
50+00
55+00
57+00
℄ PROFILE (CONT)
SCALE: HOR. 1" = 50' VERT. 1" = 5'
Pumping Station No. 2
T-Wall
Top of wall El. 21.5
Hurricane Tide El. 18.5
Existing ground surface
Sta 57+00
El. 4.0
Bottom of T-wall El. 2.0
El. 15.0
El. 11.0
60+00
62+00
LANDSIDE
RIVERSIDE
℄ Dike
12" Stone protection
Compacted gravel fill
El. Varies
Rock fill
Compacted gravel fill
Compacted impervious fill
100' Channel
Existing ground surface
Sub-drain
Crushed stone
Gravel bedding
Stripping line
Cut-off trench
Gravel bedding
El. -1.0
12" Stone protection
12" Gravel bedding
DIKE
STA 31+00 - 54+50
SCALE IN FEET
T-WALL
El. 21.5
Reinforced concrete
Compacted random fill
Compacted sand fill
El. 10
El. 4.0
El. 2.0
TYPICAL SECTIONS
SCALE 1" = 10'
L-WALL
STA 24+85 - 28+25
Building
Bit. Pavement
24" Stone protection
12" Bedding stone
12" Gravel bedding
El. 7.0
El. 1.0
El. -2.0
Compacted sand fill
Compacted random fill
REVISION
DATE
DESCRIPTION
BY
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.
WATER RESOURCES DEVELOPMENT PROJECT
PAWTUXET RIVER BASIN
WARWICK LOCAL PROTECTION
WARWICK AVENUE AREA
PROFILE AND TYPICAL SECTIONS NO. 2
WARWICK
RHODE ISLAND
SHEET 3

PLATE 15

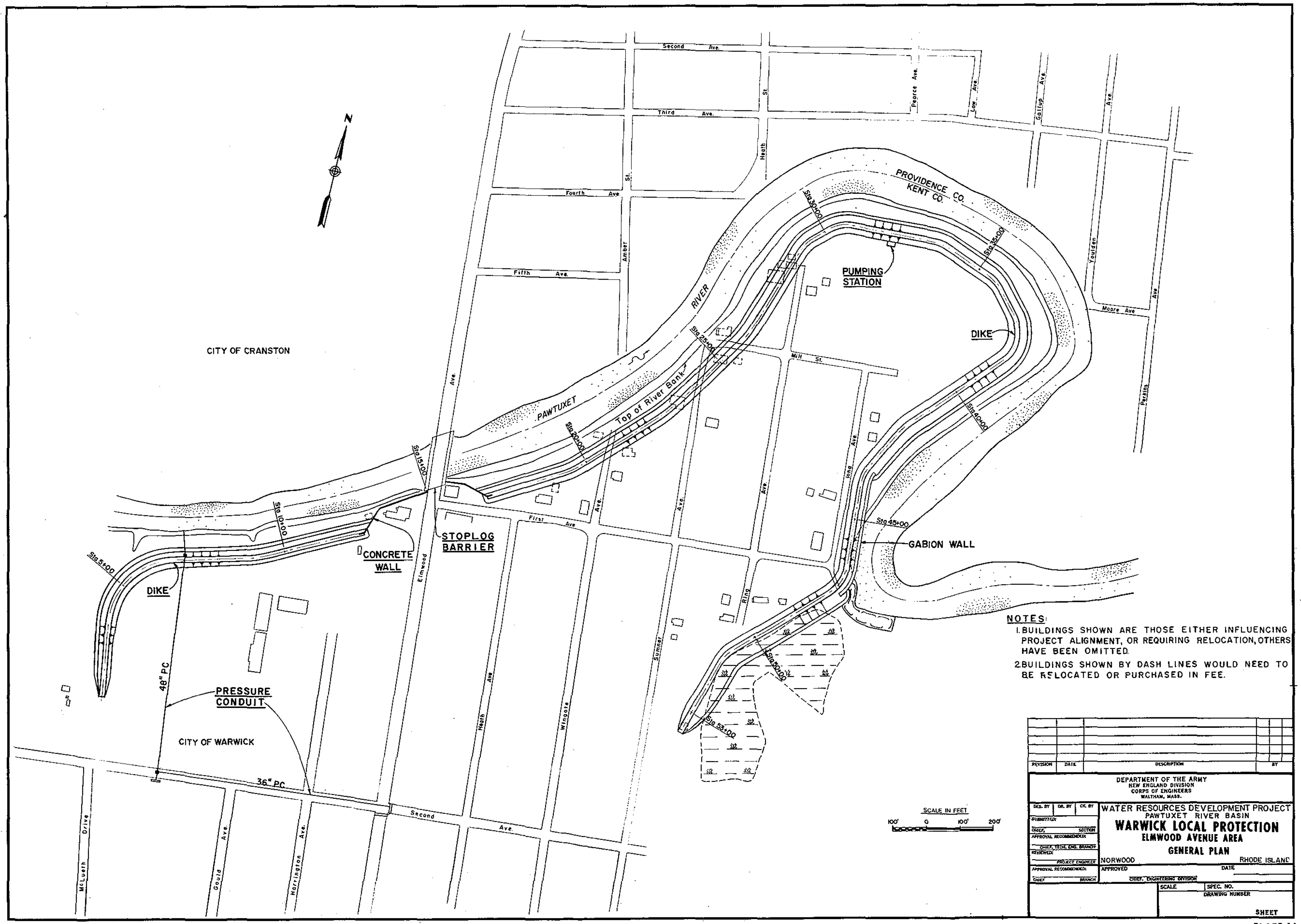
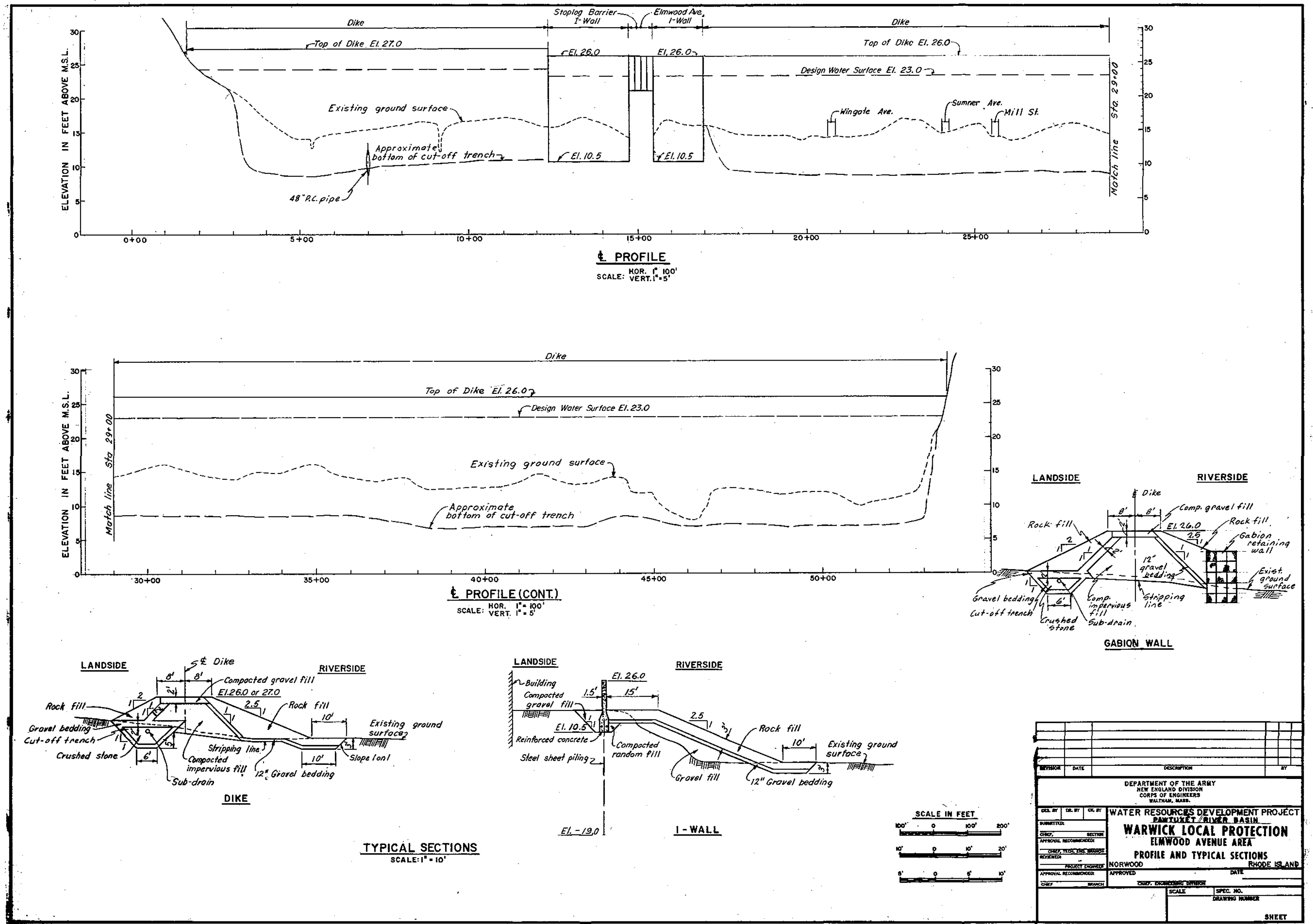

N
CITY OF CRANSTON
CITY OF WARWICK
PAWTUXET
RIVER
PROVIDENCE CO.
KENT CO.
Top of River Bank
PUMPING STATION
DIKE
GABION WALL
CONCRETE WALL
STOPLOG BARRIER
PRESSURE CONDUIT
48" PC
36" PC
Sta 5+00
Sta 10+00
Sta 15+00
Sta 20+00
Sta 25+00
Sta 30+00
Sta 35+00
Sta 40+00
Sta 45+00
Sta 50+00
Sta 53+00
Second Ave.
Third Ave.
Fourth Ave.
Fifth Ave.
First Ave.
Mill St.
Moore Ave.
Elmwood Ave.
Amber St.
Heath St.
Pearce Ave.
Lay Ave.
Gallup Ave.
Youlden Ave.
Perkins
Iona Ave.
Ring
Sumner Ave.
Heath Ave.
Wingate
Gould Ave.
Harrington Ave.
McLueth Drive
SCALE IN FEET
100' 0 100' 200'
NOTES:
1. BUILDINGS SHOWN ARE THOSE EITHER INFLUENCING PROJECT ALIGNMENT, OR REQUIRING RELOCATION, OTHERS HAVE BEEN OMITTED.
2. BUILDINGS SHOWN BY DASH LINES WOULD NEED TO BE RELOCATED OR PURCHASED IN FEE.
REVISION
DATE
DESCRIPTION
BY
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.
DES. BY
DR. BY
CK. BY
SUBMITTED:
CHIEF, SECTION
APPROVAL RECOMMENDED:
CHIEF, TECH. ENG. BRANCH
REVIEWED:
PROJECT ENGINEER
APPROVAL RECOMMENDED:
CHIEF BRANCH
WATER RESOURCES DEVELOPMENT PROJECT
PAWTUXET RIVER BASIN
WARWICK LOCAL PROTECTION
ELMWOOD AVENUE AREA
GENERAL PLAN
NORWOOD
RHODE ISLAND
APPROVED
DATE
CHIEF, ENGINEERING DIVISION
SCALE
SPEC. NO.
DRAWING NUMBER
SHEET

PLATE 16


Dike
Stoplog Barrier I-Wall
Elmwood Ave. I-Wall
Dike
Top of Dike El. 27.0
El. 26.0
El. 26.0
Top of Dike El. 26.0
Design Water Surface El. 23.0
Existing ground surface
Wingate Ave.
Sumner Ave.
Mill St.
Approximate bottom of cut-off trench
El. 10.5
El. 10.5
48" R.C. pipe
Match line Sta. 29+00
ELEVATION IN FEET ABOVE M.S.L.
℄ PROFILE
SCALE: HOR. 1" = 100' VERT. 1" = 5'
Dike
Top of Dike El. 26.0
Design Water Surface El. 23.0
Existing ground surface
Approximate bottom of cut-off trench
Match line Sta. 29+00
℄ PROFILE (CONT.)
SCALE: HOR. 1" = 100' VERT. 1" = 5'
LANDSIDE
RIVERSIDE
℄ Dike
Comp. gravel fill
El. 26.0
Rock fill
Gabion retaining wall
12" gravel bedding
Exist. ground surface
Gravel bedding
Cut-off trench
Crushed stone
Comp. impervious fill
Sub-drain
Stripping line
GABION WALL
LANDSIDE
RIVERSIDE
℄ Dike
Compacted gravel fill
El. 26.0 or 27.0
Rock fill
Existing ground surface
Gravel bedding
Cut-off trench
Crushed stone
Stripping line
Compacted impervious fill
12" Gravel bedding
Slope 1 on 1
Sub-drain
DIKE
LANDSIDE
RIVERSIDE
Building
Compacted gravel fill
El. 26.0
El. 10.5
Reinforced concrete
Steel sheet piling
Compacted random fill
Rock fill
Existing ground surface
Gravel fill
12" Gravel bedding
El. -19.0
I-WALL
TYPICAL SECTIONS
SCALE: 1" = 10'
SCALE IN FEET
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.
WATER RESOURCES DEVELOPMENT PROJECT
PAWTUXET RIVER BASIN
WARWICK LOCAL PROTECTION
ELMWOOD AVENUE AREA
PROFILE AND TYPICAL SECTIONS
NORWOOD
RHODE ISLAND